PROCEEDINGS

OF THE

National Annual Meeting

FOREST PRODUCTS RESEARCH SOCIETY

Research · Development · Production · Utilization

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AMERICAN FURNITURE MART BUILDING
666 NORTH LAKE SHORE DRIVE · CHICAGO

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MONDAY, TUESDAY AND WEDNESDAY
MARCH 22, 23 and 24

1948

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VOLUME TWO

FOREST PRODUCTS RESEARCH SOCIETY
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1948 NATIONAL ANNUAL MEETING

Opening Session 9:00 a. m., Monday, March 22

The meeting was called to order by President Fred W. Gottschalk in the Lounge Room of the Furniture Club of America. He briefly reviewed the eight sessions scheduled for Monday, Tuesday, and Wednesday, and then called attention to the general announcements in the prepared program, as follows:

Registration

There is no registration fee; the meeting is open to members and non-members.

On Sunday afternoon and evening, March 21, a registration desk will be maintained at the Hotel Sherman, the headquarters' hotel; however, no meetings or sessions are scheduled to be held at the hotel. On March 22, 23 and 24, the registration desk will be located at the Furniture Club of America on the 17th floor of the American Furniture Mart Building.

Ladies' Program

This will include a conducted tour by special bus along the lake shore drives in Chicago, and luncheon at the Edgewater Beach Hotel. The ladies' group will leave from the Society's Registration Desk at the Furniture Club of America at 12:30 p. m. Monday, March 22. A service fee of $2 will be charged.

In addition, the ladies are invited to make the special tour of the American Furniture Mart Building, Tuesday afternoon, and to attend the informal banquet, Tuesday evening.

Meeting Facilities

All technical sessions will be held at the Furniture Club of America, American Furniture Mart Building; the lounge room of the Club will be arranged for the meetings, while the main dining room of the Club will be the scene of the informal banquet.

Field Trips

A number of inspection tours are scheduled for Tuesday afternoon. Registrants may select one field trip or remain at the Furniture Club of America for the Open Forum on Finishes. The transportation fee will be $1. The tour groups will leave from the Society's Registration Desk at 1:30 p. m. Tuesday. Transportation will be provided by buses which will return at approximately 5:00 p. m.; the Mart Buildings tour will require about one hour.

Evening Banquet

The informal evening dinner which is open to all will feature the presentation of the five hundred dollar Wood Award to a university student for outstanding research in the field of forest products. Principal speakers will be Colonel Charles S. Lawrence and Rear Admiral Paul F. Lee who are prominent in Army–Navy research. Tickets purchased in advance will be $4; tickets purchased on meeting day will be $5.50, if additional facilities are available.

Preprints of Papers and Presentation

Preprints of all papers will be available at the registration desk. It is planned that each author will condense his presentation to a general summary with a period following for questions and floor discussion. Those who participate in the floor discussions are asked to present their remarks in writing to the session recorder in order that the pertinent information may be included in the 1948 Proceedings of the meeting; a special form will be provided for this purpose.

Exhibits

A number of exhibits provided by producers of forest products, suppliers of equipment or material used by the forest products industries, consumers of wood, laboratories in the wood field, etc. will be open during the entire meeting period. The purpose of the displays is to provide information for those concerned with forest products, development, production or utilization.

The president appointed Mr. Dwight W. Bensend as chairman of the election tellers to count the ballots for new officers to be installed on Wednesday at the close of the National meeting.

After brief mention of the business meeting to be held at 5:00 p. m. on Monday and a cordial invitation to attend the President's Reception, including the Paul Bunyan bar and loggers' cook shack at 6:30 p. m., the session was turned over to Vice-President George A. Garratt, Chairman of the Program Committee. Dean Garratt reviewed the need for authors to summarize their papers in a ten-minute period so that adequate time for discussion would be available. Everyone was invited to join in the discussion and to present their pertinent remarks in writing to the session chairman.

(Footnote)

Total attendance at the close of the three-day meeting was 566. The tours through the Mall Tool Company, R. S. Bacon Veneer Co., Woodworking Corporation of America, the Quartermaster Food & Container Institute for the Armed Forces, and the American Furniture Mart Building were made possible through the courtesy of the management of these organizations.

TECHNICAL SESSION I

Monday, March 22, 1948, 9:00 A. M.

General Subject: Improved Utilization of Wood and Chemical Conversion of Wood Waste

Chairman: Kenneth G. Chesley, Director of Research, Crossett Lumber Company, Crossett, Arkansas *(South-Central Regional Board Member, FPRS)*

Recorder: Frank H. Kaufert, Chief, Division of Forestry, University of Minnesota, St. Paul, Minnesota *(Chairman, Publications Committee, FPRS)*

The Importance of Economic Considerations in Wood-Waste Utilization Research

Robert K. Winters

Chief, Division of Forest Economics, Central States Forest Experiment Station, U. S. Forest Service, Columbus, Ohio

A generous amount of clear economic thinking by the chemist, engineer, or other specialist is necessary at the time waste-utilization studies are being planned and carried out. Such thinking should almost always include a consideration of the approximate quantity, character, and distribution of the waste that is suitable for the manufacture of given products, the probable cost of the waste at the plant, and the probable selling price of the products. Consideration of these items may eliminate certain studies and permit the concentration of effort on those likely to develop processes that can be useful in plant operation and in wood-waste utilization.

MUCH work has been done on the economic aspects of wood-waste utilization. Operators of forest-product plants constantly try to reduce costs of raw material and at the same time to increase net profits by its fullest economic use. In this paper, however, I wish to emphasize the importance of economic considerations in selecting, planning, and carrying out research projects in the field of wood-waste utilization.

Practically all forest industries produce a large volume of waste. This can be classified as logging waste and manufacturing waste. Logging waste includes (1) trees left standing in the woods because of low quality or excessive cull; (2) parts of cut trees left in the woods for the same reasons; (3) trees badly damaged in logging and subsequent slash disposal. Manufacturing waste includes (1) wood material not used in the primary manufacture of lumber, veneer, etc.; and (2) wood material not used in the secondary manufacture of furniture from lumber, plywood from veneer, etc. The effective use of waste is not only an individual plant poblem, it is also an industry-wide problem. To the extent that present supplies of lumber and other wood products are short, it is also a problem in which the public at large is interested.

But let's be more specific. Precisely what is included in the term "wood waste"? In practice, a number of concepts are commonly used. The Society of American Foresters, in its *Forestry Terminology,* has defined logging waste and sawmilling waste. Logging waste is "that portion of the tree which has merchantable value, but is not utilized;" sawmilling waste "that portion of the log having a merchantable value which is not utilized." The Society of American Foresters has further defined "merchantable" as follows: "Used to designate the portion of trees or stands which can be profitably marketed under given economic conditions." These definitions are truly definitive only where merchantable value is expressed in terms of a given product, or a definite combination of products. The volume of unused material in a white oak tree 22 inches in diameter may be three times as great when the tree is cut into tight-stave bolts as it would be if it were cut into sawlogs. Actually, few persons in the hardwood regions of the United States would say that tight-stave cutting produced no waste, because all material that economically could be put into tight staves was used. The given white oak tree should be converted into all products that can be made practicably and economically from it. Some operators and foresters have classified as waste only the unutilized material that could be processed economically into lumber. This concept may be valid, if no form of integrated logging or milling for products other than lumber is practicable.

Another concept of waste would include the unutilized material that cannot feasibly be used by such effectively integrated operations as the Crosset Lumber Company at Crosset, Arkansas,

the Weyerhaeuser Timber Company at Cloquet, Minnesota, the Goodman Lumber Company at Goodman, Wisconsin, and others. Even this concept will not be static or too precise. It will vary from one locality to another and within a locality from time to time, depending upon economic conditions and improvements in processing equipment. In the mountainous portions of the West, for example, far removed from the principal consuming centers of the country, timber is large and transportation costs are great. Under such conditions this concept of waste would be entirely different than it would be in the many parts of the East where close utilization of small timber is feasible. With the passing of time, however, the western concept is almost certain to change.

Still another concept of waste includes all material larger than a specified size, regardless of the present feasibility of utilization. This concept more nearly conforms to Webster's definition of waste, which is as follows: "That which has no original value or no value for the ordinary or main purpose of manufacture; parts or fragments of original stock not of a size suitable for use in making the product for which the stock was secured but which may be suitable for making another product, in which case the remaining parts or fragments are waste."

I have mentioned several concepts of waste. Others are possible, but they probably fall between the extremes given above. Certain concepts are useful for certain purposes. The last-mentioned concept is certainly the most useful in focusing attention on the supply of potentially usable wood material that undiscovered utilization techniques may possibly convert into useful products. It is approximately the concept on which most of the statistics presented in this paper are based.

The economist in wood-waste utilization research frequently makes surveys to determine the quantity of waste material produced during a given period at a plant or in a specified locality. Such a survey was made on a Nationwide basis in 1945 by the U. S. Forest Service, and the results published in Reappraisal Report 4, "Wood Waste in the United States." In this report, waste included the sound portions cut but not utilized from trees five inches and larger in diameter at breast height. The upper stems of conifers were included to a four-inch top, and the limbs of hardwoods to the same minimum diameter. Furthermore, this volume included the sound portions of trees left uncut but badly damaged in logging operations and subsequent slash disposal. It included manufacturing waste, such as the sound volume of slabs, edgings, trimmings, cutting, shavings, sawdust, etc. The total volume of waste by these definitions was 6.5 billion cubic feet, of which 2.5 billion cubic feet were used as fuel. The four billion cubic-foot remainder, which is immediately available for some use, does not include the volume made into such by-products as lath, shingles, and dimension stock.

Only a small part of the four billion cubic feet of material not at present utilized can be processed into lumber economically. Furthermore, at present only a small part of it can be processed economically into low-quality items. The cost of processing it for fuelwood and transporting it to prospective consumers would be greater than the selling price which could be charged in competition with coal, oil, and other fuels. The fact that the quantity of waste by this definition is as great as it is, should not discredit any industry or group. It is a reservoir of raw material to challenge the ingenuity of utilization research personnel.

This reservoir of raw material should be studied, with regard to its distribution and its suitability for various uses. The results of this analysis should be helpful in showing what kinds of utilization research are needed to discover processes and equipment that can make possible the maximum use of wood now wasted. Such an analysis, on a national scale, should focus attention on our national wood-

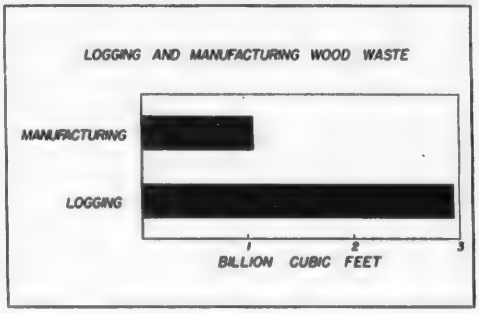

Fig. 1.

waste research problem and illustrate the type of analysis that can be made in the area tributary to any plant.

Figure 1 shows the four billion cubic feet of potentially useful material classified as logging waste and primary manufacturing waste. Nearly three-quarters of the total volume of waste is left in the woods in unutilized parts of cut trees and in trees damaged by logging and slash disposal operations. Figure 3 shows the logging and manufacturing waste distributed by the geographic regions outlined in Figure 2. The quantity of waste is greatest in the Pacific Northwest and the Southeast Regions. In the former, logging waste makes up a very large proportion of the total; in the latter, logging waste is still somewhat more than half of the total. Figure 4 shows the relative volume of the primary manufacturing waste that is in the form of slabs, edgings, trimmings and other coarse material and that in the form of sawdust, shavings and other fine material. The aggregate quantity of primary manufacturing waste is greatest in the Southeast Region.

Careful examination of Figures 1 through 4, plus some knowledge of utilization practices and conditions common in various parts of the country, permit five broad deductions:

1. Logging waste is the largest category of waste in absolute volume. Because it is also the most widely scattered, it is usually the least available economically. The principal exception to this generalization is in the Douglas-fir region of western Washington and Oregon. The concentration and transportation of this class of material normally requires relatively large expenditures of manpower. With current, high wage rates, the cost of delivery at the consuming center is likely to preclude economic utilization of much of it, until mechanization of woods work has proceeded much farther than it has at present. Accordingly, except where volumes of logging waste per acre are high or where mechanized concentration and transportation are now feasible, more intensive utilization of woods waste will very likely have to await higher wood prices or further economies in production.

GEOGRAPHIC REGIONS USED IN THIS PAPER

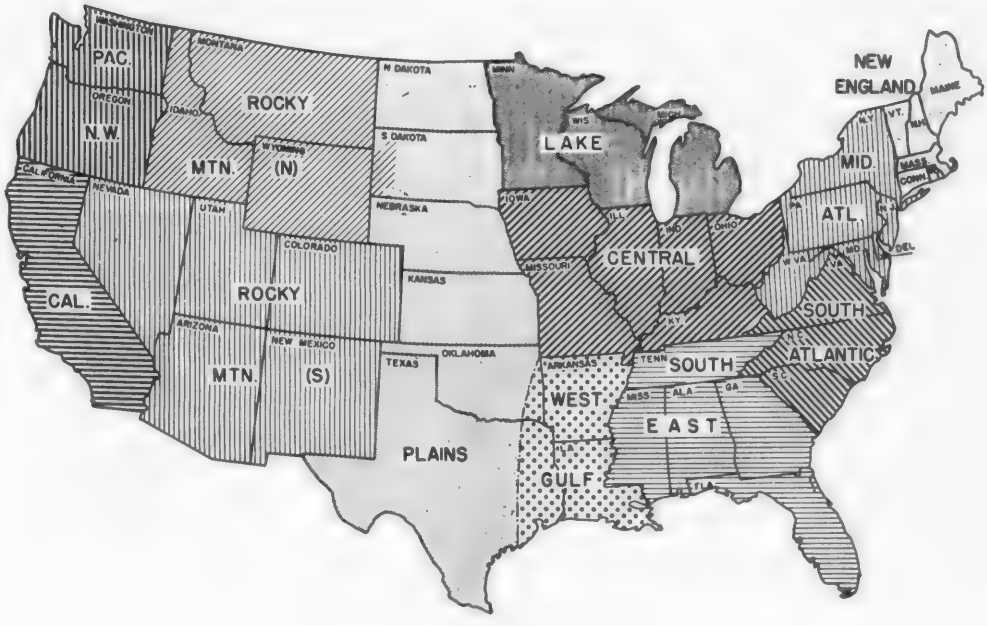

Fig. 2.

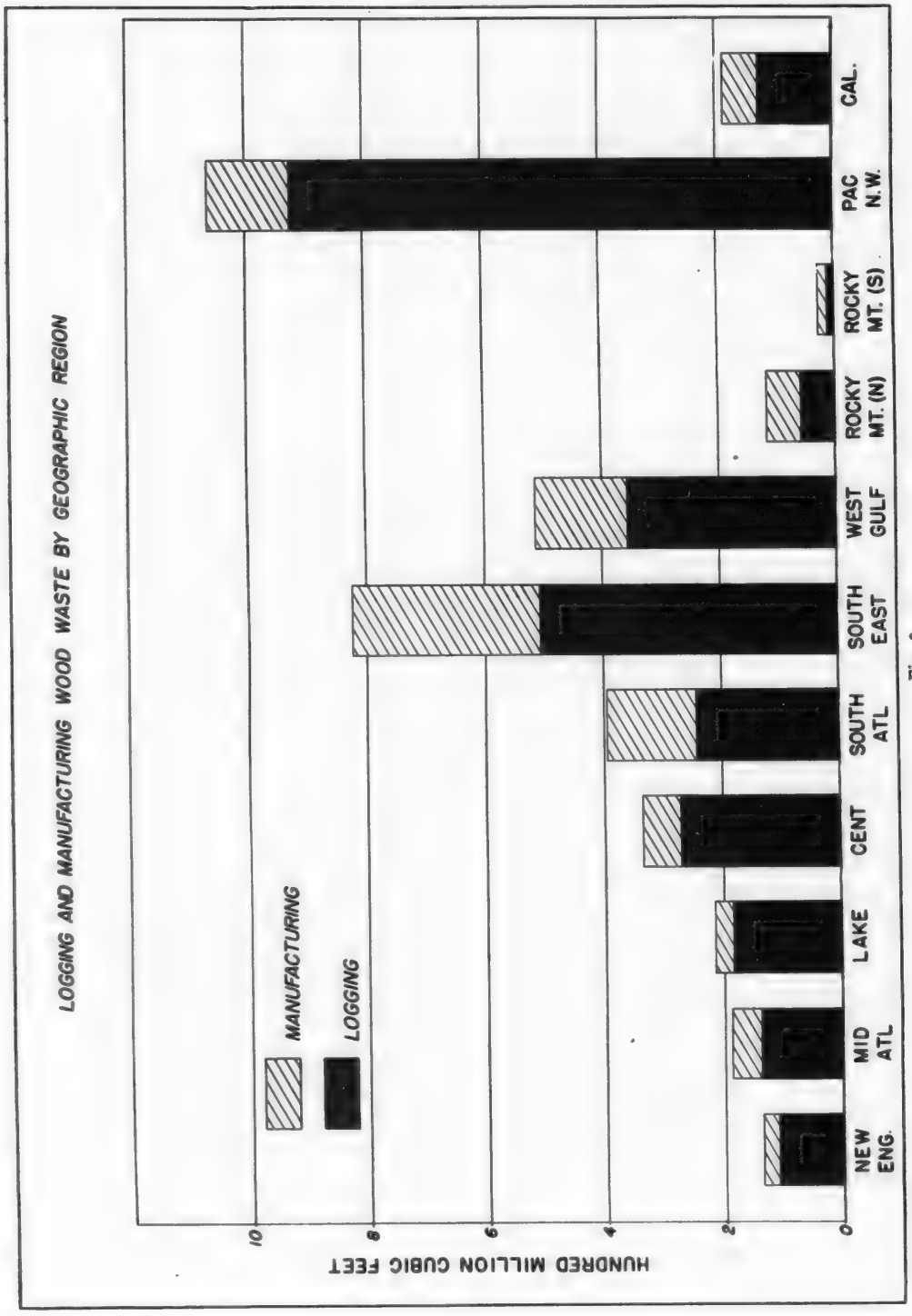
LOGGING AND MANUFACTURING WOOD WASTE BY GEOGRAPHIC REGION
MANUFACTURING
LOGGING
HUNDRED MILLION CUBIC FEET
0
2
4
6
8
10
NEW ENG.
MID ATL
LAKE
CENT
SOUTH ATL
SOUTH EAST
WEST GULF
ROCKY MT. (N)
ROCKY MT. (S)
PAC N.W.
CAL.

Fig. 3.

PRIMARY MANUFACTURING WOOD WASTE BY SIZE OF MATERIAL AND GEOGRAPHIC REGION

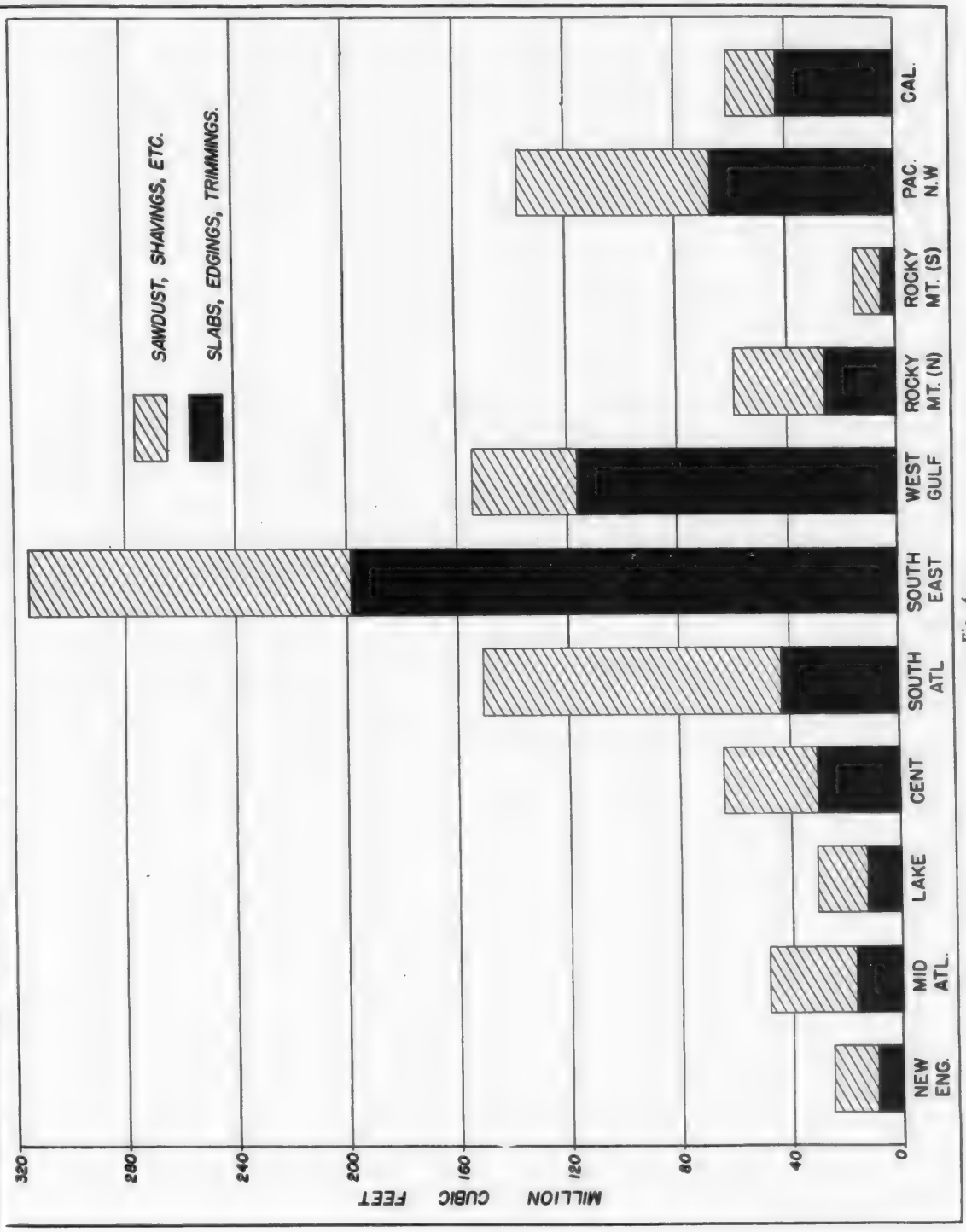

Fig. 4.

2. Primary manufacturing waste in relatively large quantities is available in the Southeast, South Atlantic, West Gulf, and Pacific Northwest Regions. In these regions, as elsewhere, this waste is partially concentrated at sawmills and other manufacturing plants. It is therefore theoretically more available than most logging waste. Actually much of it in the South Atlantic, Southeast, West Gulf and other eastern regions is in the form of slabs and sawdust at innumerable, scattered, temporary settings of small, portable sawmills. For most uses this material is not now practicably available, but must await the development of mechanized processes for picking up, transporting, and unloading it, or the development of a product that can be made from it with a value sufficient to pay the present cost of collection and transportation to the consuming plant. Where large, relatively permanent sawmills or other primary manufacturing plants are common, as in nearly all parts of the West and at some locations in the Lake States and West Gulf Regions, a supply of waste sufficient to attract potential users is available at or near given utilization points.

3. Wood now used as fuel can be diverted into other uses wherever the wood price exceeds the fairly low fuel value. In most regions more by-product material of primary manufacturing plants is burned as fuel than is left unutilized. This diversion of wood from use as fuel is often feasible where power is relatively cheap, as in the case of electric power in parts of the West and South and natural gas in parts of the South. This use transfer could make available for higher use a large additional wood volume, which in some instances is relatively concentrated.

4. For the country as a whole, the volume of slabs, edgings, and other coarse waste material is greater than the volume of sawdust, shavings and other fine material. In the Pacific Northwest Region a considerably larger volume of sawdust and shavings is used for fuel than is the case with slabs and edgings. In this region, therefore, the present and potential volume of fine waste material is larger than the corresponding volume of coarse material.

5. Lumber production statistics for the Pacific Northwest Region indicate that, for 1945, about 68 percent was Douglas-fir, 17 percent ponderosa pine, 7 percent western hemlock, and the remaining eight percent western red cedar, Sitka spruce, white fir and miscellaneous species. For practical purposes, this means that both the logging and milling waste for all products is distributed among the species in about the same proportions, although inclusion of pulpwood would certainly increase the proportion of hemlock somewhat. In this region, therefore, research on Douglas-fir logging and milling waste seems to offer the maximum opportunity for waste reduction. Considering lumber production of the total west, ponderosa pine accounts for 25 percent of all production. Since western mills are normally large enough to supply considerable quantities of concentrated waste, research on ponderosa pine mill waste seems to be justified. In Texas and Louisiana, where larger mills still operate, lumber production is approximately 60 percent southern pine, 15 percent gum (red and tupelo), 15 percent oak, and the remainder miscellaneous species. Here research on pine mill waste seems to be in order, with gum and oak following in rank of importance.

Problems of research workers employed by wood-using companies depending on local raw materials will, of course, be dictated by local considerations. Peculiarities of the product manufactured, plus favorable conditions for concentrating nearby wood waste, may indicate the desirability of almost any kind of utilization research. In setting up research programs in the broad field of waste utilization for public and quasi-public agencies, however, consideration should certainly be given to those wastes that are in ample supply, sufficiently concentrated for practical exploitation, and produced by mills that are not likely to exhaust their supplies of operable timber in the immediate future.

Another important economic consideration in selecting a research project in wood-waste utilization is the determination of the kinds and quantities of wood waste available in an operating territory that can be supplied to a given plant at a feasible cost. In some instances, the choice between two otherwise equally meritorious research projects may hinge upon the economic availability of a given kind of

waste material. A producer of corrugating board recently wanted to run some tests to determine if hardwood sawmill slabs would produce a satisfactory fiber for his use. He procured an experimental supply from a nearby sawmill. At this point he called in for counsel a man who knew something of the local sawmill industry. This local man recognized at a glance that the species represented in the experimental slabpile were bottomland species and not at all representative of the supply available generally in the territory of the corrugating board mill. Tests run on the experimental slabs, therefore, would not indicate the suitability of the average run of local sawmill slabs for the indicated purpose. The mill operator was advised to make a survey of the quantities and kinds of wood waste tributary to his plant and the probable purchase price and transportation cost of each, and to test those kinds that seemed to offer possibility for economic use.

Some of the failure to utilize waste is due to lack of technical processes for making a useful product from material now wasted. To a much larger degree, failure is due to the lack of cheap, efficient procedures for handling and concentrating widely scattered pieces of waste. Economists are sometimes called upon to assist equipment designers in planning and carrying out time studies to develop machines and procedures for handling and concentrating waste wood. One operator has found that slabwood from small sawmills can be loaded economically on wood dollies approximately the size of a 1½-ton truck bed. These dollies are spotted at several mills in a given locality and are filled with slabs by the off-bearer at about the cost of piling the slabs on the usual waste heap. Once a day the purchaser's truck driver loads a full "dolly" on his truck by means of a winch, cable, and pair of skids. At the same time he leaves an empty "dolly". By a very simple "trial and error" study, this purchaser discovered the combination of equipment and process that provided him with a usable raw material at an acceptable cost.

Throughout this paper, I have talked about economic considerations in wood-waste utilization research. By this I do not mean to imply that research organizations need be "padded" with "stand-by" economists waiting to give counsel when called upon. A generous amount of clear economic thinking by the chemist, engineer, or other specialist is, however, necessary at the time waste-utilization studies are being planned and carried out. Such thinking should almost always include a consideration of the approximate quantity, character and distribution of the waste that is suitable for the manufacture of given products, the probable cost of the waste at the plant, and the probable selling price of the products. Consideration of these items may eliminate certain studies and permit the concentration of effort on those likely to develop processes that can be useful in plant operation and in wood-waste utilization.

Discussion

Professor Hereford Garland (Michigan College of Mining and Technology): Mr. Winter's major premise that economic thinking is needed in planning wood-waste utilization research is certainly well put. We need to take a broad view of any proposal for the use of wood waste and this should extend from the original location of the raw material to the product in the sonsumer's hands. We need to beware of over-enthusiasm and wishful thinking. In this we run the risk of being branded as ultra conservative or as obstructionist, but this is a cross that the forest products researcher must bear if he wants to retain his professional standing over a period of years.

Wood-waste utilization research is aimed at shifting a potential raw material into the category of actual raw material, in other words, making it wanted. This is a basic economic concept. There are several methods of approach, all of which need to be considered and each of which tends toward the goal of increasing raw material utilization. In certain cases, any one of the following methods might conceivably solve the problem of waste utilization:

(1) Reduce the cost of delivering the raw material to a new process.

(2) Reduce the operating costs of a new process.

(3) Minimize the cost of delivery of a new product to the consumer.

(4) Increase the desirability of the product.

(5) Discover or create a market for the product. It is possible that selling alone might solve the problem.

(6) Connect an existing raw material with an existing process or an existing market. This is not forest products research in the narrow sense, but it does solve the basic problem through a combination of technical and economic effort.

It is granted that the economist should have a part in selecting problems in wood-waste research. Who else should participate? Certainly the process technologist should have a prominent place, although he should not dominate the activity, as is too often the case. The materials-handling engineer will often be a key figure in the consideration of utilizing wastes. Finally, to obtain the broadest possible view, the successful business executive in the related fields should be consulted, since he has had to be concerned with both the technical and the economic aspects of production.

Mr. Herbert B. McKean (Timber Engineering Company): I believe that it was Mark Twain who pointed out that there is more said about the weather and less done about it than any other thing. I sometimes think this is true of wood-waste utilization. In view of some of the papers to be presented here, perhaps this is not true.

Certainly any technologist should consider the economics before setting out to find the answers to waste utilization. Therefore, it is good to open this three-day program with economics as the keynote. I feel so strongly on this point that I want to reemphasize what Mr. Winters has said. In general a successful research project must consider economics from start to finish. A wood product manufacturer will insist that a product from waste have a good chance of adding to the profit side of his ledger before he starts manufacturing such a product. He is justified in this attitude.

It is unfortunate that the largest volume of unused wood is in the forests. Economics dictates that there are more possibilities at the mills. Certainly, if we don't feasibly collect slabs at small mills, we can't expect to collect tops and limbs from the forest.

The diversion of wood from fuel to a higher form of utilization often presents problems, the main one being relatively inefficient boilers. When you have been running a boiler essentially as a waste burner, the costs of conversion to true power production are not easy to compute. Yet this is one of the major economic problems in a waste-utilization program.

Mr. Winters has indicated the most important species available in waste. Certainly effort should be concentrated there. But the products developed must be capable of production from mixed woods. Economics generally prevents segregation of waste by species.

There are two other points I want to mention:

(1) Too often the technologist becomes so enthusiastic about his solution to the waste problem that he may come to believing that his one new product is the entire answer. Most people will agree, however, that again economics dictates against an attempt to manufacture all of the four billion cubic feet mentioned by Mr. Winters into one product. In fact it will take hundreds of products.

(2) Finally, one of the main points scientists miss is marketing. I believe most of us, when we work on waste, envision the operator, himself, adding to his plant facilities and manufacturing and selling the new research-developed products. I believe we should remember that all firms normally have a sales force trained to sell boards or furniture or whatnot to regular customers. Now we give that sales force a new product. Generally, it means new customers and probably a larger sales staff. My suggestion here is, "Let's try to develop, wherever possible, products that are a natural addition to the line already being produced by the plant whose waste is to be used."

Mr. Rudolph Willard (Snyder and Willard, Consulting Engineers): Mr. McKean has raised the point in his discussion of the paper that it is desirable for by-products to be such that they can be sold to the same customers as the main product and be handled through the same marketing channels and by the same salesmen. I should like to point out that proper marketing is the most important aspect of a by-product program. In this respect, by-products are no different than the main product. From the viewpoint of the dollar, it is no use to make any product unless you can sell it at a profit.

We have found by experience that most hardwood lumber salesmen do a poor job of selling hardwood dimension stock. The specialized dimension salesman does much better. If this is true of products as closely related as rough lumber and dimension stock, what about the case where a sawmill whose main product is lumber develops such by-products as charcoal or chemicals.

In selling your by-products you will get better results if you use marketing channels and salesmen suited to each product rather than using your regular selling organization.

Mr. G. Colucci (Southern Box and Lumber Company): The first step in wood-waste utilization should tend towards better utilization of logs and lumber, so as to reduce the percentage of waste. A rotary veneer mill in the Southeastern states, by changing the process of cutting veneers from the old-fashioned method of tearing by hand, stacking the sheets on conveyor tables and cutting a number of sheets at one time, to a method of clipping green sheets of veneer singly as same is unrolled from the log while it is traveling under the clipper, has increased the yield from 84 to 98 percent. To put it another way, the waste has been reduced by 87 percent.

Professor F. H. Vogel (Alabama Polytechnic Institute): I want to say that Mr. Winters' remarks have fallen on fertile ground. Many of us here are engaged in wood utilization research, and we are concentrating heavily on the practical, economic angles. At Alabama Polytechnic Institute in Auburn, our Forestry Department is initiating research work in wood utilization directed strongly toward the practical side.

Let me give you one example of how carefully we look at a new problem now before we rush headlong into a recommendation. Down in Alabama we have a very progressive sawmill organization which is worried about its waste in pine slabs and edgings. The owners want to find a profitable outlet for this material, and the first thought of research advisors was to utilize the waste for the production of pulp. According to the old standards of sawmill utilization, there should have been roughly a cord of waste wood per thousand board feet of lumber sawed, which would have justified the installation of a pulp unit. The technical problems would have been easy. Actually, however, the utilization experts checked the various economic factors, including new standards of modern sawmill utilization brought about by horizontal band resaws and remanufacturing plants, and it was found that only a small fraction of the expected waste would be actually available. It looks as if that mill alone cannot economically support a pulp plant. The owners are still pursuing the problem, and they will find a utilization angle that will pay.

As a representative of a publicly financed school laboratory, I recognize the value of fundamental research, and I would never belittle the value of it. I know, however, that all of us engaged in research are thinking more and more in terms of the financial practical ends of our investigations. We are primarily interested in the technical data, but consider it as a means to an end.

FOREST PRODUCTS RESEARCH SOCIETY

An Analysis of Wood Losses in Redwood Logging

Emanuel Fritz

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Logging is unavoidably accompanied by wastes. These are occasioned by inability to convert the entire tree into lumber. The losses in redwood logging are particularly heavy, because of the great size and weight of the trees and the rough, steep ground on which they grow. The impact of a falling redwood with the ground causes most of the loss and consequent waste. Internal defects, and the rough unmerchantable tops aggravate the volume losses.

On a 29-acre area, containing originally 4,099,778 board feet of sound merchantable lumber, or 141,170 bd. ft. per acre, the operating losses of originally merchantable contents totaled 43,270 bd. ft. per acre. After fire-proofing the area, there remained 96.6 cords of sound but surface-charred wood per acre, all of it suitable for conversion by some chemical means into other products. Bark alone totals 23.6 cords per acre.

These data give the specialists in wood conversion an idea of the volume of waste wood available in one region, and present a challenge to their technical skill and ingenuity in finding some form of utilization.

WHAT becomes of the woody content of a redwood tree? How much of it appears, eventually, as a useful product? How much of it is lost and characterized as "waste"? Where do the losses occur, and what is the form of the waste? These questions must be answered before a timber owner can determine what and where changes can be made to reduce the avoidable losses. The inquiry will give him the basic volume data he will need when considering conversion of the unavoidable waste into a useful product. The economist, interested in the business aspects of losses, and the forest-products researcher, interested in finding a use for the waste, are equally concerned in the answers.

The analysis here reported is based on a prewar intensive inventory, on a 29-acre area in Humboldt County, California, of the original stand of timber, the logs removed and the material left on the ground. Also, a sample run of logs was followed through the sawmill to determine the mill tally of the lumber as a check against the woods log scale. Part of the area was logged by the high-lead system and the remainder by the slack-line system. Both systems, as used on this area and operated by powerful steam donkey engines, are recognized as being quite destructive. To give clearance for the yarding and back-haul cables, all but the smallest trees are felled, even though they may not all be utilized. These systems also account for some of the breakage that adds to the waste, the amount varying widely with the efficiency, skill, and interest of the logging crews. On the study area, the cables reached 2,000 feet, and in one "corner", they reached 3,000 feet into the tract adjoining the study area.

Forest Description

Logging in virgin redwood stands has always been accompanied by a large amount of waste. It is likely that, as long as virgin stands exist, there will be a volume of waste well in excess of that in other virgin forest regions. To understand why this happens, the redwood forest must be described.

The typical commercial redwood forest is predominantly redwood *(Sequoia sempervirens)*, with a small to significant percent of "white woods"—Douglas-fir, white fir, and, in the more northern parts, Sitka spruce and hemlock. The percent of hardwood is small. Toward the edges of the region, the percent of white woods may be so high that, in the past, logging was not profitable. Currently, the situation is materially improved.

The typical redwood forest is one of mixed sizes and ages. On a single "forty," trees may vary from one foot in diameter to more than ten feet, and from under 100 years old to well over 1000 years. Often the hearts of the larger and older trees, particularly those suffering basal injuries in the past, are quite rotten. This has an important bearing on the amount of waste of sound wood. The great height and mass of the larger trees, and the steep rough

ground on which most of them grow, makes felling without breakage exceedingly difficult. Added to these adverse logging characteristics, is the softness of the wood and its high moisture content. A butt log, six feet in diameter and 20 feet long, often weighs more than ten tons, while the larger ones may reach 40 tons. All these characteristics conspire to make waste quite large. Were the trees sound and not so large, soft, and heavy, the losses would be small. It is interesting to note that the Douglas-fir, harder and lighter than the redwood, though often as large, is felled with inappreciable loss. In consequence, it can be felled down hill, whereas the redwood must be felled uphill.

Procedure

First, a topographic map was made of the area, and on this each of the 1,153 trees was located. During and after the felling and bucking operations, notes were made of the felling breakage, log lengths and diameters, utilized and merchantable length, length of the top, and defects. The positions of the fallen trunk and the logs were entered on the map. Since all defects could not be appraised until the logs were separated, a more intensive check was made of the dimensions, scale, and defects of each log after it was yarded and loaded on the cars. This gave the "car scale" figure and represents the actual utilization of each tree in the form of logs. After yarding, the stuff left on the ground was surveyed for missed logs, chunks, and other material originally from the merchantable part of the trunk. Concurrently, on a spot upon which logging was completed, the refuse left on the ground was measured—the smaller stuff being piled for measurement like cordwood. As already indicated, a mill-scale study was made on a several days' run of logs totalling 167,007 bd. ft., log scale.

In this study, only the merchantable tree length was considered in determining the volume losses, and these were divided into 12 broad categories, two of which (rot and shake) were classed as natural, and the remainder as operating losses. The refuse left on the ground included tops, limbs, unmerchantable logs and chunks, and was separated into two size classes.

Significant Logging Data

The study yielded a large amount of data which cannot be reported in its entirety. Not only is space unavailable, but some of the material is not germane to the occasion. Consequently, only the more significant figures of interest to the utilizationist, are presented.

The study area, which was moderately steep, embraced 29.04 acres. It bore 1,120 redwood trees, of which 672 were felled and produced one or more merchantable logs each. In addition, there were 57 old redwood windfalls from which 94,989 bd. ft. log scale was salvaged. There were nine partially utilized Douglas-firs that yielded 22,663 bd. ft. log scale, and 24 white firs, 12 of which yielded 17,053 bd. ft. log scale; the other 12 were not felled. The 448 redwoods and 12 white firs that were under merchantable size and not felled, were pulled down during logging and added to the debris.

Gross scale of all felled redwoods, assuming each to be sound, was 4,554,698 bd. ft. log scale. (All log scale data herein reported are by the Spaulding log rule.) Natural losses—rot, hollow butts, rift cracks, and shake—totaling 454,920 bd. ft. or, roughly, 10 percent, reduced the total gross scale to a net merchantable scale of 4,099,778 bd. ft., or 141,170 bd. ft. per acre. All operating losses, from felling through loading on cars, totaled 1,256,786 bd. ft. log scale, or 43,270 bd. ft. per acre and 30.66 percent of the original net merchantable log scale of 4,099,778 bd. ft. The actual log scale shipped to the mill, as scaled on the cars, is therefore 2,842,992 bd. ft., or 97,900 bd. ft. per acre. This represents 69.34 percent of the original net merchantable log scale.

The above summarized data are based on the log scale as made *in the woods* for the author by C. R. Buell, a company scaler of several years' experience, who had made personal studies of scaling. The traditional method of scaling redwood logs is to scale them full by the Spaulding log rule and then to deduct 30 percent from the day's total to provide for defects. The resultant scale is generally referred to as the "Humboldt Scale." The custom was established because of the great difficulty of appraising the extent of defects, the inability to observe the extent of decay and in-

ternal felling cracks. Scaling out defects is also very time-consuming and often holds up loading. On this study an attempt was made to scale out defects. Then, to check the scaler's judgment, a mill tally record was made of the product of marked study-area logs totaling 167,007 bd. ft. log scale. This check revealed that the mill tally under-ran the woods scale by 9.5 percent. This under-scaling of defects resulted mainly from understimating losses by fire scars (a slash fire had run overpart of the area) and internal felling cracks. Consequently, the loss data summarized above must be corrected, and the car scale of 2,842,992 bd. ft. becomes 2,572,908 bd. ft., or 88,721 bd. ft. per acre. This is then 62.8 percent of the original merchantable log scale. In other words, the loss of sound wood from the merchantable portions of the redwood trees was 37.2 percent. Table 1 presents the corrected data in tabular form.

TABLE 1.—INVENTORY OF VOLUME LOSSES BY SPAULDING LOG RULE ON 29.04 ACRES. REDWOOD ONLY

Number of felled redwood trees	Gross scale, board feet	Natural losses		Net scale of merchantable contents, board feet	Opering losses[1]		Mill tally of lumber	
		Board feet	Percent		Board feet	Percent	Board feet	Percent
672	4,554,698	454,920	9.98	4,099,778	1,526,870	37.2	2,572,908	62.8

[1]Corrected from mill tally data.

Sources of the Losses and Waste

The waste left on the ground is made up of trunk chunks caused by felling breakage, crushed logs, unmerchantable logs, missed merchantable logs, tops of merchantable trees, limbs, bark, stumps, and all the smaller unutilized trees. The chunks are made as short as possible by sawing the breaks out of the trunk with a minimum loss, but occasionally a bucker (cross-cutter) overestimates the extent of the shattered wood and cuts out more than may be necessary. Felling breakage alone accounts for 20 percent of the operating loss. The crushed logs result from trunks containing considerable center rot. These occasionally smash flat like a dropped watermelon, as they strike the ground, or they are crushed when other trees accidentally fall across them. Although there is generally much excellent wood in the chunks and the smashed rotten-center logs, it is of such size and form that it is rarely possible to convert it into lumber and then only by a separate operation. The unmerchantable logs are usually those containing too much center rot to justify their removal and transport to the mill; at the mill, such logs cause considerable loss in handling. Missed logs are those that are overlooked by the yarding crew or that have broken loose from the yarding lines and have rolled into a gulley or canyon beyond reach. The tops of the merchantable trees are often 75 to 150 feet long, and occasionally they have a butt diameter of three feet and sometimes five feet, but they are so rough, because the limbs are so large and close together, that merchantable lumber cannot be made from them. The stumps on the study area averaged five feet tall. All felling on this area was by hand-sawyers. Shortly thereafter, power saws were adopted and stumps were sawed lower. However, in spite of the fact that stump wood is generally from 75 to 90 percent clear stock, it is generally so tough and "springy" that, even though the stumps were cut very low, it is often desirable that the trunk be long-butted and the tough part left in the woods. Brought to the mill, this tough wood is often trimmed off the boards.

The unfelled smaller trees—448 redwoods, in this study, varying from 12 to 30 inches in diameter—add a considerable volume to the slash debris. They are pulled down during yarding, and are beyond salvage after the cross-cutters have left and yarding has commenced. On this study, 114 additional trees in this small-diameter category were felled because they would yield at least one good log.

It is noteworthy that for each six-inch diameter class of felled trees,—31–36"------ 61"–66", 67" and over,—the operating loss percentage was approximately the same, about 30 percent of the merchantable volume. The actual total volume of the losses by six-inch diameter classes, however, varied with the number of trees in each class, or from 4.04 percent of all waste for the 31"–36" class, to 44.03 percent for the 67"-and-over class. It is evident therefore that, of the losses from merchantable portions of the trees, about one-third

was originally good wood from which lumber could have been made had it been possible to do so. This fact is of importance to the laboratory researcher in that it gives him some basic data on the character and convertibility of some of the debris. Obviously, straight-grained trunk wood is easier to convert than limbs and rough tops. However, part of the losses is carried to the mill and there appears on the refuse conveyor.

Table 2 presents the operating loss data by diameter classes.

TABLE 2.—VOLUME OF OPERATING LOSSES, BY DIAMETER CLASSES, OF MERCHANTABLE REDWOOD TREES ONLY. DETERMINED FROM WOODS LOG SCALE
29.04 Acres

Stump diameter classes, inside bark (Inches)	Number of redwoods felled and utilized	Net scale of sound merchantable contents, bd. ft., Spaulding rule		Operating losses[2]	
		Amount	Percent	Amount by Spaulding rule bd. ft.	Percent of total losses
12-30[1]	114	108,601	2.64	41,711	3.31
31-36	92	171,251	4.18	50,795	4.04
37-42	95	308,210	7.53	89,658	7.13
43-48	90	436,421	10.63	115,891	9.22
49-54	62	387,777	9.45	107,219	8.53
55-60	66	506,649	12.33	155,204	12.40
61-66	45	452,477	11.04	138,753	11.04
67 and over	108	1,728,392	42.20	557,555	44.03
	672	4,099,778	100.0	1,256,786	100.0

[1]All but two trees, 20" to 30". From these 114 trees at least one log was made.
[2]Not corrected for underscaling as indicated by mill tally.

Progress Toward Reducing the Losses

While the slack-line system of logging is still being used, it is definitely on the way out and is being replaced by short-haul Diesel yarders with a high-lead rigging and, more generally, by crawler-type tractors. The slack-line system is likely hereafter to be used only in the wet season and on the steepest terrain, when and where tractors are not practicable. The Diesel-yarder high-lead system is not nearly so destructive as the slack-line, and is used only where tractors cannot maneuver or when a sufficient number of tractors is not available. The tractor is now so common and experience in using it so well advanced, that the operating losses on tractored areas are much less than on slack-line and high-lead areas. In addition, the cutover land is left in better condition for the growing of future timber crops. The tractor is reducing the amount of debris by at least the volume of most of the unmerchantable trees which can now be left standing, plus some logs heretofore considered too defective to salvage and some good logs heretofore lost into gulleys. The volume of debris will continue large, however, particularly that resulting from the breakage in the larger trees.

Currently there is much study and some experimenting on the "re-logging" or salvaging of small stuff to a small mill located in or near the woods. The production of split products, such as grape stakes, posts, crossties, and shingle and shake bolts, has been undertaken when and where a contractor can make a success of it.

Felling breakage is being steadily reduced, when experienced "fallers" are available. The necessity of using inexperienced fallers during the late war, and since, has not helped this situation, but there are signs of improvement. Four different methods of gently lowering large heavy trees, instead of felling them in the traditional manner, have been promoted. Two were tried out. To date none has proved to be practicable. Several operators have assigned a bulldozer-equipped tractor to several sets of fallers, the function of the bulldozer being the preparation of a "bed" or "layout" into which the tree is to be felled. The machine merely smooths the surface, pushing out obstacles, shaving off humps, and filling in depressions. This development has resulted in saving more of the merchantable length of the bigger trees without breaks.

Considerable thought and experimentation is being given also to salvaging clear slabs and cants from large rotten-center logs, *i.e.*, logs which heretofore had to be left in the woods or, at a loss, were transported to the mill and converted into lumber. So far, the gas- or electric-powered chain saw, with teeth shaped and

filed for ripping, seems to give greatest promise for ripping off four thick slabs or cants from outside the rotten area. Such cants are free from knots and should produce a high percent of clear, vertical-grain lumber. Reduction of felling breakage and the utilization of rotten-center logs, responsible as they are for the greatest losses in volume and in money, are receiving most attention currently. Other losses are slight in comparison when tractors are used. But it must be repeated, for the benefit of the utilization researcher who is interested in finding some use for the woody debris, that he still will have a huge volume on which to work.

Returning to the so-called unmerchantable trees—unmerchantable because they are too small (under 30 inches) to permit profitable conversion into lumber—when they are added to the debris they may be lost irretrievably. If left standing, they would provide a nucleus for a later cut. They are generally suppressed trees and are growing very slowly. They are considered young, but actually may be several hundreds years old. Inasmuch as they have a remarkable capacity to recover from suppression, when released from competition with the larger crop trees, their growth rate accelerates at a remarkable rate. A 24-inch tree growing at the rate of considerably less than one percent per year, may accelerate to five percent or more. Such a tree can double its volume in 20 years. In the meantime, it will serve as a seed tree for reforesting the spaces left by the removal of the crop trees.

Final Waste Volumes After Logging and Burning

While the losses reported in the foregoing pages give an indication of the volume of woody refuse developing from the merchantable portions of the trunks of the utilized redwoods, they do not include the volumes of the tops and limbs, nor the volume of the smaller trees pulled down during yarding. Furthermore, it is customary to fire the cutover land after logging to reduce fire hazard. Such fires consume most of the smaller pieces and leave only the larger chunks, tops, and logs. These, themselves, are much reduced in diameter. Under present conditions, much of the original splintery material would be difficult to collect for a chemical-utilization project. Should a chemical utilization of the waste develop at some future time, the raw material will have to be collected promptly after logging.

On the study area a slash fire entered part of the plot, and later the entire area was burned before the logs were bucked and yarded. This once was the general custom, and the sequence ordinarily was felling, peeling, burning, bucking, yarding, with sometimes another fire to fire-proof the property or to prepare it for planting. This is not now the practice, and burning is withheld until after yarding. Also, planting has been abandoned in favor of selective logging or the leaving of the smaller trees for seed trees.

To get an idea of the volume of sound wood left after logging, all the debris on a sample 1.46-acre piece, triangular in shape and with the apex at the spar tree, was measured. Small stuff was piled and measured as cordwood and the larger pieces were measured for cubic-foot content and the figure converted into cords. It was found that on this study area the sound wood remaining on the ground and available for conversion into pulp or other fibe product, amounted to 96.6 cords per acre, of which 78.3 cords was material larger than ten inches in diameter and three feet long. The remainder was smaller stuff down to two inches in diameter. All of this wood had charred surfaces, a fact of importance to the chemist.

Bark

Redwood bark is so tough and stringy that it must be removed from the logs prior to sawing, if well-manufactured lumber is expected. Until the war, except for one company which peeled at the plant, peeling was done in the woods. For some years the writer has endeavored to encourage peeling at a central point for certain economies and for centralizing the bark itself for further utilization. One large and three smaller companies are currently making insulation fiber and additional products from the bark. Other products are possible.

At the butts of large trees, the bark is from four to eight inches thick, occasionally 12 inches. It rapidly becomes thinner away from the butt and into the top where it may be only one inch thick.

To obtain an estimate of the bark volume, a computation was made from the dimensions of 732 trees on 31 acres, and from their bark thicknesses up to a point where it ceases to be one inch thick. It was found that, on this 31-acre area, bark totaled 2,360 cubic feet per acre, or 23.6 cords per acre. A converting factor of 100 cubic feet per cord was used since the bark stacks rather solidly.

Summary

Logging in old-growth redwood is accompanied by a large volume of waste, much of which is suitable for conversion into pulp or other fiber products or into chemicals. Even if current practices are much improved, the waste volume, inevitably and unavoidably, will be great.

On a 29.04-acre of virgin redwood timber, a close check was made of the disposition of all woods in the merchantable portions of the trees. It was found that this area supported originally 4,099,778 bd. ft. of sound merchantable timber, or 141,170 bd. ft. per acre. Of this, 62.8 percent appeared as lumber in the sawmill, or 88,721 bd. ft. per acre. The remainder, or 1,526,870 bd. ft., was lost somewhere during felling, logging, and milling. Twelve categories and sources of losses were recorded, of which felling breakage was the heaviest, being close to 20 percent.

After the slash fires, there remained 96.6 cords of sound wood per acre in the miscellaneous sizes and shapes. The volume of bark, distinct from that of the wood, was found to be 23.6 cords per acre.

Discussion

Dr. Harry F. Lewis (The Institute of Paper Chemistry): Professor Fritz has been concerned with redwood wastes in lumber production. I should like to extend his remarks to take in the amount of material usable in a chemical-wood conversion operation which results from redwood logging and lumbering operations.

It is practically impossible to estimate accurately the amount of wood substance in a redwood tree. Both the specific gravity and moisture content vary over wide ranges within the same tree, so a volume estimate is not easily convertible. In spite of this, rough estimates of the wood substance have been made and are given below in tabular form to show that, if readily available, they could support a sizable chemical utilization operation.

A mill, in producing one million board feet of redwood lumber, will yield at the same time the following material:

Losses in logging -----	300,000 B.F. or	600	tons	green basis
Losses in the mill --------		1144	"	" "
Stumps and roots ----------		700	"	" "
Chemical wood substance in tops (not included above)		300	"	" "
Total ----------		2744	"	" "

Half of this amount would result daily from a mill cutting 500,000 board feet. There are mills of this size.

The above figures contain duplicate counting of some material. Because of this and the great variations between operations, they must be considered as approximations only, with an accuracy of $\pm$ 10 to 15 percent. They do not include factory waste.

Only a part of this, the mill waste, is now located where it would be available for use. Stumps and roots and other forms of wood waste would require special methods for processing and recovery. This volume of waste is concentrated in a relatively small area and could be utilized if economically feasible methods were available.

To the above woods waste material can be added 395 cords of bark per million feet board measure (Spaulding), and for the year at The Pacific Lumber Company a potential bark production of 395 x 150 or 600,000 cords of green bark substance. Much of this is lost before the log reaches the mill, and a part of the bark on the log reaching the mill is damaged beyond profitable reduction.

It should be pointed out that the above wastes are all green wastes, since green redwood is half water and green bark even more than that. The actual weight of dry wood and bark substance will be less than half the green weight listed, and in a chemical utilization plant it is the dry wood substance which yields the by-products and furnishes the basis for yield data.

Not only is there an annual production of waste material, but there are available on the cutover land stumps and tops with a diameter

of three feet and less which have not been burned in the slash fires. Only a relatively small area of such land has been cleared for agricultural purposes. A vast amount of this material can be obtained.

This subject should not be left without pointing out again that these figures are only approximate. They are incorporated for the purpose of showing that wastes exist in such amounts as to warrant their consideration as a source of chemical or fibrous raw materials.

The first speaker on this program pointed out the importance of putting utilization operations on a sound economic basis. I second this heartily, with the added provision that processes not currently economical may become either economical or necessary under changed conditions in other chemical industries. The fundamental studies concerned with utilization need to be made and the industrial process established—then, when it is needed, it is ready. Changes in petroleum technology or in coal technology may change the direction of their interests and may open the way for ours. Here is redwood wood-substance currently available and also a reserve ready for future needs.

The Small Log Gang Sawmill as a Factor in Our Present-Day Utilization Problem

W. D. Hewlett

Heaps Engineering (1940) Ltd., New Westminister, British Columbia

The past dissipation of many natural resources of the North American continent has led to a state of transition from abundance to mere sufficiency. If steps are not taken, by governments and private enterprise alike, to develop and implement plans for the conservation and maximum utilization of the remaining resources, then this state may shortly become one of insufficiency.

This paper outlines one method of sawing lumber which can materially assist in solving this problem.

IN THE days of our forebears, the forests on the North American continent were vast and made up of large stands of big timber. Today great man-made changes have taken place, most of the large timber has been cut, and we find that the large percentage of what is left is in small trees, scattered stands, and remote regions. This condition has lead to a change in sawmilling practice, with the old-time large sawmill situated in the middle of a vast tract of timber largely replaced by many small mills scattered over a large area. This changed situation involves either the frequent moving of the mill or the transporting of the logs over long distances. The additional cost of hauling the logs over greater distances is not necessarily such a big problem, however, because once the logs are loaded, the use of modern transportation methods and good roads tends to hold down the cost of extra mileage. The big increase in cost is to be noted in the handling of the small log in the woods and loading it for transportation. To offset the additional cost of getting the log to the mill, it is necessary to find means of reducing the cost of processing even the smallest log and of increasing the yield obtained.

Great strides have been made by government officials and private owners in the conservation of standing timber, both by the application of better logging methods and by reforestation, but unfortunately the development of the small economical sawmill, with one notable exception, has not kept pace with this trend. In consequence, we are now faced with a situation in which a large percentage of the country's usable small timber is either being processed into a less valuable commodity (most wastefully sawn into inferior lumber), or left in the woods to rot.

This, then, is the problem toward whose solution all farsighted men interested in the conservation of our natural resources should be working.

The Utilization Problem

The utilization problem, as posed to us today is to produce economically the maximum footage of usable lumber from the whole tree, and to develop further economical means to obtain the most valuable utilization of the residue. Mr. C. A. Rishell, Director of Research, National Lumber Manufacturer Association, is authority for the statement that "Even with the utmost care the tree which was cut in the forest will produce only slightly more than a third of its volume into lumber," and he goes on to say that "The volume utility of the log must be raised."[1] With this latter contention we wholeheartedly agree.

Recent developments have been largely concerned with the utilization of the heretofore so-called waste encountered in the production of the finished wood products, including slabs, sawdust, shavings, small logs, etc. These developments, generally speaking, call for complex processing techniques, requiring considerable capital investment to produce various products from a large quantity of wood. Th-

[1] "A Tree Goes to Market", *Southern Lumberman.*

bulk of this wood, if economically sawn initially, would have a higher value yield as lumber.

Why create waste and then evolve a use for it? How much better to find ways to curtail this waste before it occurs. Then the utilization problem is reduced to a minimum.

The present-day types of equipment available to the sawmill man for cutting the small log are few, and can be briefly summarized as follows:

1. The large band mill, cutting both large and small logs, requiring a large permanent installation with a high capital investment. To cut small logs on this type of installation requires the same horsepower and manpower for a greatly reduced output. It is a most uneconomical operation.
2. The small band mill, for cutting small logs only, requires a permanent installation, carriages, shotgun feed, log turner, high manpower and power for an average present-day yield from the log.
3. The small circular mill, easily moveable, can be set up anywhere and is cheap. It requires very high manpower and power to produce a low output of inferior lumber with a minimum yield from the log.
4. The small log gang saw, which may be either portable, semi-permanent, or permanent. The initial investment is reasonable, and this type of mill obtains the highest production for manpower and power used and the largest yield from the log.

This paper is concerned with the small log gang saw and its place as a factor in our present-day utilization problem.

History of the Gang Saw

The principle of gangsawing is to secure the accurate sawing of the maximum number of boards from the log or cant by multiple saws in one passage of the log through the machine. Experience has shown that the vertical frame, mounting many short, straight, thin, accurately-spaced saws, and moving with a reciprocating motion provides the most practical, economical, and efficient method of gangsawing.

The gang saw, or frame saw as it is called in some countries, has been used as a method of sawing lumber from the log for many generations. Probably the earliest use was in Europe, where maximum utilization has ever been a major factor in the economy of the various countries. Despite the fact that conservation and reforestation have been brought to a high art in the European countries, no effort has been spared by both manufacturers and lumbermen alike to evolve methods of sawing lumber which would produce the maximum yield from the log. To this end, the gang saw is the most widely used method.

The popular conception of a gang saw is that of a very heavy, slow-speed machine with a heavy vibration, slowly producing the largest volume of accurately-cut boards from cants previously processed on a headrig. This was very true in the past and even today many such installations are still in use to the benefit of their operators. However, on this continent, where we are usually leaders in development, the picture has changed and the basic gangsaw has been improved and modernized out of all recognition. Today, it is a high-speed, smooth-running machine, which can be installed speedily for a reasonable outlay in any location, to cut both round logs and cants.

Of necessity, over the years, many and varied methods of sawing lumber have been evolved to suit the many requirements which have to be met. All of these methods definitely have a place. All can and are being improved upon. No one method of sawing is a cure-all and none can be suggested as the best until all the facts of the individual case have been assessed.

Mr. Nelson Courtland Brown, Professor of Forest Utilization at the New York State College of Forestry, in his book entitled "Lumber", states: "The great advantages of a gang saw are accuracy of lumber cut, increased volume production, and low cost per unit of production."

The most modern and highly developed gang saw in use today is constructed almost entirely of steel for stiffness, strength, and reduced weight. It has a large, all anti-friction bearing crankshaft connected to the sash by an all anti-friction bearing connecting rod, the whole being a balanced unit. This allows for

very high speeds. This machine incorporates hydraulic drive for the feed works and hydraulic pressure on the top feed rolls. By these means the following important advantages are obtained:

1. Infinitely variable feed, forward and reverse
2. Instantaneous stopping of the feed without stopping the saw.
3. Uniform pressure on the power-driven top-feed rolls, which is essential when cutting round logs, the rolls climbing easily over rough spots and protrusions on the log.
4. High number of cutting strokes, in excess of 375 per minute.

The small log gang saw is especially developed for the processing of unbarked round logs into boards or dimensions, with

A. Highest output for a minimum of labor and power,
B. Minimum waste by use of small kerf saws,
C. Precise accuracy of sawn lumber,
D. Reasonable capital investment.

It is designed to cut a large diameter range of small logs without changing the setup.

Operation of the Gang Sawmill

The gang mill operation differs from that of the regular band or circular mill in that the mass production system is applied. All the lumber is cut to a given width from any required number of logs without changing the setup of the machine. An important part of this operation is the sorting of logs to a size to suit the setup of the saws, which, in turn, are set in the sash to suit the required width of lumber. To change the setup of the saws requires the stopping of the machine and the actual setting takes approximately ten minutes. With this in mind, a schedule can be made so as to waste as little time and material as possible. As saws will usually run about four hours before regrinding, this is a convenient time to change the setup.

In some parts of the world, notably the Scandinavian countries, logs are sorted down to one inch diameter classes. This represents the ultimate in utilization. Where logs are to be cut into all 1 inch or 2 inch boards, the sorting is not so necessary, but it is still desirable to a limited degree.

The modern gang saw is very flexible as to installation, as is indicated by the four following types:

1. The completely mobile saw, mounted on a large truck frame and moved readily on its own wheels, as used by the German Panzer Division in World War II.
2. The complete mill, including power, conveyors, log haul, edger, cut-off saw, and gang saw with carriages, mounted on one large pair of skids approximately 36 inches by 60 feet. Such units, moved in the woods by caterpillar tractor, are being used in southern Washington, Oregon, and British Columbia.
3. The semi-permanent installation, intended to be knocked down and moved at intervals.
4. The permanent setup installed on cement foundations, either by itself as an entity or incorporated into a large mill.

From this it can readily be seen that locating the modern gang saw is not dependent upon the machine itself, but rather upon the availability of timber, species and size of logs, transportation problems, and the type of operation that is required. Some ideas as to the possibilities follow.

A logical location for a single unit is an area where there is available a large volume of moderately straight and uniform timber, where the logs may be sorted so that a run of several hours can be obtained with logs that do not vary too much in diameter.

The two-gang sawmill, with two units in tandem, is probably the most efficient installation possible today. With this, all side lumber is cut from two sides of the log in the passage through the first unit; the log is then turned down and the side lumber from the other two sides is taken off in the second unit. The center of the log may be cut by the second unit into quarter-sawn lumber, ties, squares or timbers, as required; this eliminates 70 percent of the otherwise required edging and gives the maximum possible yield from the log.

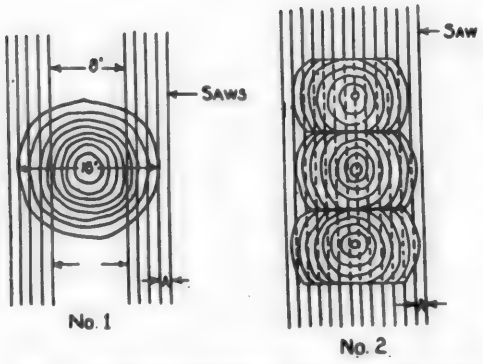


Fig. 1.—Method of reducing logs to lumber in the two-gang sawmill.

The possibilities of this two-gang setup are indicated in Figure 1, which shows how logs can be piled for cutting on the second unit.

Combination Mills

The log gang saw is an excellent partner to a band or circular rig, where a fair percentage of logs are too large for the gang saw and the remainder too small economically to cut on the head rig. In a pine mill, for instance, the large higher grade logs can first be cut on the head rig, taking off the uppers, while the cants can be stored and later put through the log gang saw. The smaller logs can be sawn direct on the gang saw, thus obtaining the maximum yield economically.

Increased Utilization by Gangsawing

Small Saw Kerf

The gauge of the saws used in the gang saw may vary in cutting different species of timber and with the different maximum rates of speed required. Gauges range from 14 down to 17.

An indication of the economy of gangsawing is shown by the use of 14-gauge saws, swaged to 5/32 inch, as compared with a standard circular saw operation. The resultant saving of 7/32 inch in kerf, when 1 by 12 inch boards are sawn, amounts to one board foot for every 4.571 linear feet of board sawn, or a saving 21.87 percent in saw kerf alone.

Accuracy in Sawing

The saws in the gang mill are mounted in hangers parallel to each other and positively positioned at the required distance apart by spacers, which are machined to 0.001 inch, and a clamping device on the frame. Thus the saws are unable to deviate from the line of the cut.

American Lumber Standards allow as much as 1/4 inch between rough and surfaced lumber, to take care of variations in sawing which may occur when the saw deviates from the true line of cut. Gangsawn lumber is absolutely accurate and therefore no more than 1/8 inch need be added to the thickness for planing.

Slabs

With the correct setup of the saws and the log properly lined up towards the saws through the facilities incorporated in the gang mill, no

Fig. 2.—Slabs from band-saw.

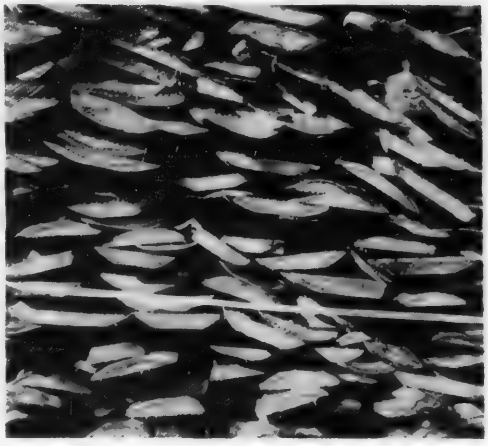


Fig. 3.—Slabs from gang-saw.

slabs thicker than one inch are sawn. Figure 2 indicating the slabs taken from a band mill and Figure 3 showing those from a log gang mill, both cutting approximately the same size and species of logs, reveal better than statistics the difference in waste where no resaw is used.

Overrun

Overrun may be defined as the actual amount of sawn lumber obtained over and above the amount given by a log scale. Because of the small kerf, accuracy of the cut, and minimum slab, the overrun obtained by gang sawing is large. On checks made in areas using the Scribner Log scale, few instances have been found of an overrun showing less than 50 percent. In one mill cutting with two gang saws the average overrun taken over a period of a full year was 55.4 percent.

Miscuts

The nature of the operation is such that miscuts seldom occur.

Material Spoilage

No spoilage of boards by dogging or turning is found, as these operations do not take place in gang sawing.

Uniformity of Cut

The uniformity of cut with the gang saw is most impressive. Figure 4 shows a typical pile of gang-sawn lumber. In this pile 200 boards were calipered at four corners and a variation of less than 1/25 inch (1 mm.) was found.

Grade Recovery

It must be stressed that, as with any method of sawing, the round-log gang saw has its limitations, the chief of these being that cut-

Fig. 4.—Uniformity of lumber sawn with a gang-saw.

ting round logs for grade is NOT a primary function of this method.

In this connection it is interesting to consider just how much grade is obtainable from the small log and how much cutting for grade is actually accomplished in an average mill, also the percentage of grade accidentally obtained in cutting by the gang saw. To illustrate this, the following figures are presented from a large Eastern Canadian mill, where a gang saw and a circular mill operate side by side:

Grade	Circular Mill Production	Gang Sawmill Production
No. 3 and better	33%	50%
No. 4	24	20
No. 5 and 6	31	27
Outs	12	3

Volume Recovery

To illustrate volume recovery, let us take as an example a 12 inch diameter log, 16 feet long. The actual volume of this log is 150.796 board feet. According to the Scribner scale, 79 board feet should be produced from this log and most circular mills will obtain this. By the use of a band mill, we may expect to obtain 25 percent overrun, which will give us 98.75 board feet. By the use of the gang saw, we should obtain 50 percent overrun, which will give us 118.5 board feet.

From this we see that, of the total volume of the log, we obtain:

By circular sawing	52.17%
By band sawing	65.4%
By gang sawing	78.48%

which shows a big step in the right direction.

Let us consider just what can be accomplished if such a saving were spread over a wide area. We will base our discussion on the production figures obtained from the Southern Pine Association, as compiled in 1945 for the 11 southern states exclusive of Tennessee. These figuers give the annual cut of softwoods in this area as 7,300,000,000 board feet. It is estimated that approximately 16,000 mills were in operation to produce this volume of lumber, with 10 percent of them using band head saws and the other 90 percent using circular head saws. It is further estimated that the circular mills produced 75 percent of the total annual volume, or 5,575,000,000 board feet. If we apply a saving of 50 percent obtained by sawing with the gang-saw method, as compared with the circular saw, this converted into annual saving in this area alone shows a potential production of 2,787,500,000 board feet more usable lumber from the same amount of logs.

It follows that the annual yield from the same log scale is increased from 7,300,000,000 board feet to a potential 10,087,500,000 board feet, without increasing production costs, by the use of small kerf saws and a method of sawing accurate and uniform lumber. The magnitude of this potential saving can readily be seen, if it is applied to the whole continent. It presents a challenge to all farsighted lumbermen.

Output

As in the case of any other type of mill, the output of the gang saw is dependent upon many factors, such as type of installation, species of timber, size of logs, and, most important of all, the ability to keep a constant supply of logs moving to the saws. This entails a steady feed of logs to the sawyer, as well as the provision of the correct equipment to enable him to feed the logs top to butt into the gang saw as fast as it will cut them. This, at first glance, may not appear to be such a big problem; however, from a look at the following production table, which is republished by kind permission of Mr. Roy B. Peterson,[2] it may be readily seen that the number of small logs that are required to keep the modern gang-saw working to maximum capacity is very large.

The following figures were taken from a late model Swedish log gang saw, 24 inch stroke, 325 strokes per minute, cutting softwoods, the average length of the log being 16 feet:

Top Diameter of Log, inches	Feed Rate Per Stroke, inches	Approximate BFM Per Hour In International Scale, No Overrun Included	Number of Logs Per Hour
6	1 7/8	2400	119
8	1 5/8	4500	88
10	1 1/4	5220	74
12	1	5700	55
14	7/8	6900	47

At Prairie City, Oregon, an 18 inch Model with a speed of 375 strokes per minute, cutting unsorted random diameter (8 to 16 inch) softwood logs with average length 16 feet, cut

[2] "Survey of the German logging, lumber, and woods products machinery and equipment industry." Report No. 409.

9,540 board feet in one hour and 48 minutes, on a trial run.

In British Columbia, a 26 inch Swedish Model at 310 strokes per minute has averaged a daily cut of 35,000 board feet per 8-hour shift over a period of several years.

From the records of a New 36 inch Record gang saw installed in December 1947, we find that an inexperienced crew of operators over a period of 149 hours cut an average of 5,472 board feet log scale per hour with unsorted logs averaging 14 inches in diameter.

Summary

Is the small log gang saw a factor in our present-day utilization problem? If a method of processing lumber from the small log will fill the following requirements:

1. Produce accurately cut and uniform lumber,
2. Reduce the unusable slab from the log,
3. Reduce the amount of sawdust made in sawing the log,
4. Reduce the amount of shavings, power and maintenance required when planing lumber, by initially cutting the rough lumber accurately, and
5. Economically cut the smallest possible log into good lumber,

and will do these things without increasing labor or power consumption, then this method economically produces the most footage of usable lumber from the whole tree.

The small log gang saw will materially assist in the accomplishment of all the above points. Thus, it is a definite factor in our present-day utilization problem.

Discussion

Prof. Charles S. Walters (University of Illinois Agricultural Experiment Station): There are two "factors" that have not been adequately covered in this paper. Certainly the gang saw Mr. Hewlett has described is a fine addition to the sawmill equipment field; however, it is not a cure-all and it should not be operated as a head saw—only as supplemental equipment. The data in the paper on grade return do not specifically state that softwoods were cut, but the grades do. On quality hardwood logs, I believe a higher return of grade-lumber can be secured by using the band or circular head saw to remove the outside boards, and using the gang saw only for cutting logs of lower grades, marginal logs, or cants that have had upper grades of boards already removed. The utilization problem in the hardwood area is not "to produce economically the maximum footage of usable lumber from the whole tree," but to produce economically the maximum footage of usable, *high-grade* lumber from the whole tree. We already have too many mills sawing for footage and not for grade.

I know Mr. Hewlett favors any practice that will conserve timber supplies. However, the saw described is designed "to reduce the cost of processing even the smallest log." By the same standards it may condone or encourage the cutting of smaller timber, thereby defeating attempts to conserve timber supplies through proper forest management. If the cutting practices in the woods are maintained or improved, and the saw is used to cut small marginal logs that have been brought to the mill in an attempt to improve utilization practices, then I am in favor of more gang mills.

Mr. Rudolph Willard (Snyder and Willard, Consulting Engineers): Mr. Walters has raised the point that, if small hardwood logs are cut into lumber on a gang mill, the grade of the lumber will be lower than if the logs are cut on a single head saw and are properly turned for best grade realization. This is certainly true where the resulting lumber is graded on N H L A rules and each grade sold at current market prices. But if a man were to utilize the full output of the log, I cannot see where this loss would apply. There is only a certain part of the log which contains defects and I fail to see how the method of sawing would increase or decrease the board footage of defective stock. I believe that standard hardwood lumber grading rules distort the picture in such a case.

Prof. Emanuel Fritz (University of California): The round log gang mill is an important factor in realizing a greater lumber tally from small logs. It cuts smooth lumber of uniform thickness, and its thin blades reduce the loss in sawdust. It has one drawback, in that

the logs cannot be turned for the highest grade recovery. However, that is not an important factor in the common grades of small logs. Anyone with a sufficiently large volume of small common logs would be passing up a profitable bet if he were to give no consideration to the modern small log gang mill.

Mr. G. Colucci (Southern Box and Lumber Company): The writer knows no method whereby greater utilization of a log can be obtained than by the utilization of a gang sawmill with thin blades. It is true that if the lumber has to be sold, it might not grade as well as lumber sawn on a band mill where the log is turned in such a way as to secure the maximum amount of better grade boards. But if the lumber is used by the same mill which produces it, the percentage of better grades will be the same as lumber produced by any other method. Furthermore, where the production warrants it, by using two gang mills just as many better boards can be obtained as by any other method of sawing.

Mr. W. G. Raoul (Cavalier Corporation): I would like to see circles of various sizes to represent cross sections of logs, as sawn by ordinary circular mills and as sawn by gangs. It was my belief that the gain of the gang over the circular would increase with the size of the log. Since the meeting, I have rather hastily laid out such a diagram for very small logs, and it seems that this gain is quite large on the smallest sizes and does not increase uniformly for larger logs. I assumed that gang-sawn lumber could be cut $\frac{1}{8}$ inch less in thickness, because of the greater accuracy of sawing. This is perhaps an extreme case, and of course the type of lumber desired would have a great deal to do with this assumption, but for many circular mills the variation in thickness is startling.

I wonder if rising prices of stumpage will not force a movement toward centrally located mills which can get more out of the log. Such mills could pay higher log prices than the small portable units. Mills in cities can sell waste for fuel, and can afford to put in automatic cut-off saws to reduce slabs to stove-wood length. All the papers on utilization of waste presented at this meeting stressed the fact that waste must be *concentrated* to be of any use.

Utilization of Low-Grade Hardwood Lumber

C. D. Dosker
President, Gamble Brothers, Inc., Louisville, Kentucky

THE utilization of low-grade hardwood lumber presents one of the greatest problems facing the hardwood producing and consuming industries today. As the quality of our hardwood timber declines and more lumber produced from second-growth timber must be marketed, the need for research in the utilization of low grades becomes more and more urgent.

This problem is not one that involves the sawmill operator alone. Rather, it starts with the timber owner—or tree farmer, if you wish —and ends with the final fabricator who must use this lumber.

To attack this problem, it is necessary to develop adequate data from which safe conclusions may be drawn. Who will undertake this work, and how it may be consummated are details which none of us can determine here. I would suggest, however, that this Society can call the attention of the entire wood-using industry to this problem, and recommend that the Trade Associations of those industries particularly involved cooperate to a common end and under a coordinated plan in order to produce the requisite data. In such an activity, the National Association of Furniture Manufacturers and the Southern Furniture Manufacturers Association should combine their efforts with those of the Hardwood Dimension Manufacturers Association, the Northern Hardwood and Hemlock Association, the Appalachian Hardwood Producers and the Southern Hardwood Producers in a cooperative study. The last-mentioned group has already started such an investigation and active work should be underway shortly, but it should be co-ordinated with consumer groups.

In my opinion there are four phases of the problem for which data must be obtained.

1. Market Studies

Market studies must be made to determine the present usage of hardwood lumber by grade, species and quantity in terms of "end products." These studies must provide data as to the length, width, and grade requirements of the finished rough blank dimension sizes into which the various grades of lumber are currently being converted. We know that the case goods manufacturers requires long cuttings for solid parts. We know, also, that the core material for his plywood is also usually in long lengths. The novelty furniture manufacturer calls for shorter stock. The chair manufacturer requires a different class of material and so, also, does the kitchen and breakfast room furniture manufacturer. The total requirements for length and width of final cuttings must be determined, because only by so doing can the proper grades of lumber be channelled into proper usage.

2. Log Grade Studies

The timber owner must develop log classifications or log grades. Much work has been done on this to date and, from personal experience, I am convinced that logs can be so graded or classified, by examination of external defects as well as heart defects, that the grade out-turn in lumber can be predetermined within reasonable limits. Only by log classification and a willingness of the timber owner to see that logs are channelled properly can we support the lumber and plywood industry as it is currently operating in this country. Without some realization of the situation and cooperation on the part of industry we are bound to suffer, unless we begin now to properly channel the basic raw material of this entire industry, our hardwood timber, into proper end usage.

3. Log Yield Studies

We must develop log yield studies by log grade and diameter classifications so that we may determine in advance the potential "grade out-turn" of the log to be sawn into lumber or cut into veneer. We must know in advance how logs of a specific grade should be sawn or cut as to thickness to meet the grade requirements of the ultimate fabricator.

4. Methods of Conversion

We must study current methods of conversion of logs into lumber and veneer, and of lumber and veneer into "end products," from the standpoint both of the mechanics of breakdown of the logs into lumber and veneer, and of the mechanics of the conversion into wood parts. There have been too few mechanical improvements in the wood conversion industry over the last fifty years, and I am sure that an intensive study would reveal new possibilities in equipment and processes that would bring economies which would be of tremendous benefit to the industry. We must break from our traditional ideas.

Having stated the over-all problem as I see it, I would like to deal specifically with the conversion of the cutting grades of hardwood lumber into sizes used in fabrication.

The conversion of hardwood lumber need not and should not involve guess work. There are a few fundamental principles and a little simple arithmetic, which, if followed, will easily permit the safe estimating of yields of boards into the various lengths and grades of the parts which are needed.

In order to accomplish this, it is necessary, first of all, to know and understand completely the grading rules for hardwood lumber. Without this knowledge one is completely at sea, for it is these grading rules which provide the basis for predetermining the "cuttings", or yield, that may be expected by:

(a) Length and width of cutting required.
(b) Number of cuttings permitted.
(c) Percent of the total area contained in the board.

Table 1 gives the requirements of various grades of lumber in brief form. As hardwood lumber is generally graded from the poorer face, this table will give a picture of the number of cuttings permitted to yield the required percentage of the total surface area of a board in usable material. It does not show what can be expected from this board in the way of either sound or clear cuttings of a specific length, which may require in your finished product, but it will tell you whether it is possible to obtain certain lengths of cuttings from certain grades of lumber.

As the grade of No. 2 Common lumber is not always a clear cutting grade, provision is made in the grading rules for special grades in which No. 2 Common may be procurred on a clear cutting basis if desired.

Table 2 shows most of the commonly used hardwoods and their types of standard cuttings.

TABLE 1.—CUTTING REQUIREMENTS FOR STANDARD HARDWOOD GRADES

(See Rule Book for exceptions with various species)

FIRSTS Widths: 6" and wider Lengths: 8 to 16 feet			SECONDS Widths: 6" and wider Lengths: 8 to 16 feet			SELECTS Widths: 4" and under Lengths: 6 to 16 feet			No. 1 COMMON Widths: 3" and under Lengths: 4 to 16 feet[1]			No. 2 COMMON Widths: 3" and wider Lengths: 4 to 16 feet		
*S.M.	% Clr. Face	No. of †Cuts	*S.M.	% Clr. Face	No. of †Cuts	*S.M.	% Clr. Face	No. of †Cuts	*S.M.	% Clr. Face	No. of †Cuts	*S.M.	% Clr Face	No. of †Cuts
4 to 9′	91⅔	1	4 & 5′	83⅓	1	2 & 3′	91⅔	1	1′	100	----	1	----	1
10 to 14′	"	2	6 & 7′	"	1	Reverse side cutting sound.			2′	75	1	2 & 3′	66⅔	1
15′ & up	"	3	8 to 11′	"	2	4′ and over shall grade on one face as required in Seconds, with reverse side of board not below No. 1. Common or reverse side of cuttings sound. See Rule (Par. 69) defining edges on reverse side of boards 4 and 5" wide.			3 & 4′	66⅔	1	4 & 5′	50	2
			12 to 15′	"	3				5 to 7′	"	2	6 & 7′	"	3
			16′ & up	"	4				8 to 10′	"	3	8 & 9′	"	4
			6 to 15′ S.M. will admit 1 additional cut to yield 91⅔% Clr. Face.						11 to 13′	"	4	10 & 11′	"	5
									14′ & up	"	5	12 & 13′	"	6
									3 to 7′ S.M. will admit 1 additional cut to yield 75% Clr. Face.			14′ & up	"	7
												2 to 7′ S.M. will admit 1 additional cut to yield 66⅔% Clr. Face.		
Minimum cutting: 4" x5′ or 3" x 7′									Minimum cutting: 4" x 2′ or 3" x 3′			Minimum cutting: 3" x 2′		

*Surface Measure.
†Cuttings.

After studying Tables 1 and 2, it becomes immediately apparent that knowledge of grades is extremely important. However, there is one thing that the grading rules do not tell you, namely, that there are variations in types of board within each grade. While these variations do not affect the ultimate utility of the board, due to the location of defects, they do materially influence the yield of the board when converted into the requirements of a specific industry.

Typing of these boards has a great bearing on the sequence of operations that should be followed in converting any given board to obtain maximum yield in length and width of cutting. The type of board will determine whether it is best to first rip it parallel to its edges, or to cross-cut it to the length of the cuttings, in order to obtain maximum yield.

TABLE 2.—TYPES OF CUTTINGS IN STANDARD GRADES OF HARDWOODS

(C. F. indicates clear face, S. indicates sound)

	Standard Grades				Special Grades	
Species	Fas	Sel	No. 1	No. 2	No. 2A	No. 2B
Ash	C.F.	C.F.	C.F.	C.F.	----------	
Basswood	C.F.	C.F.	C.F.	S.	*C.F.	S.
Beech	C.F.	C.F.	C.F.	C.F.	----------	
Birch (Yellow)	C.F.	C.F.	C.F.	C.F.	----------	
Cottonwood	C.F.	C.F.	C.F.	S.	*C.F.	S.
Elm†††	C.F.	C.F.	C.F.	S.	----------	
Gum Sap	C.F.	C.F.	C.F.	S.	*C.F.	S.
Gum, Black	C.F.	C.F.	C.F.	S.	*C.F.	S.
Hickory	C.F.	C.F.	C.F.	S.	----------	S.
Magnolia	C.F.	C.F.	C.F.	S.	*C.F.	S.
Maple, Hard	C.F.	C.F.	C.F.	C.F.	----------	
Maple, Soft	C.F.	C.F.	C.F.	S.	----------	
Red Oak	C.F.	C.F.	C.F.	C.F.	----------	
White Oak	C.F.	C.F.	C.F.	C.F.	----------	
Poplar	C.F.	C.F.	C.F.	None	C.F.	S.
Walnut	----------					
Willow	C.F.	C.F.	C.F.	S.	*C.F.	S.

*Grade obtainable by special purchase only not standard.

The types of boards, as I choose to classify them, are as follows:

1. Rip Type.
2. Cross-Cut Type.
3. Neutral Type.

In the *Rip Type,* the defects are staggered throughout the length and width of the board and, in many cases, will be relatively parallel to the edge of the board. This type of board is usually seven inches or over in width.

The *Cross-Cut Type,* or cross-cutting board, is one in which the defects are usually edge defects, such as wane or knots along one edge, pith or heart along one edge or through the center, large knots in close relationship to each other, or defects that go largely across the major portion of the face of the board, such as shake or worm holes. Also included in this category are boards six inches or under in width, which would produce excessively narrow cuttings if the boards were ripped as a first operation.

The *Neutral Type* is, as the name implies, the type of board in which the length advantage or cross-cutting advantage is not clearly established. It will develop in ultimate yield approximately the same percentage of cuttings by length or width that one would obtain by either cross-cutting or ripping as the first operation. Defects, such as knots parallel with the edges, heart center, splits parallel with the edges and similar defects, are included in this type board. The neutral boards are usually six inches and over in width.

In grade yield studies made in converting the various types of boards, I was interested to find that, in the No. 1 Common grade of lumber, the various types of boards were rather uniformly divided, there being approximately one-third of each type in the average run of lumber. However, in the No. 2 Common grade the percent of rip type was materially greater.

In the matter of yields, a great deal depends upon the size and quality of the logs from which the lumber has been produced. Today, with an increased proportion of lumber coming from small logs, one may expect considerable variation in the types of boards within the species of lumber and the kind of timber from which this lumber was produced.

Plate No. 1 is intended to illustrate ripping and cross-cutting grades of boards. Examination of the several figures will indicate what I mean by types of boards within the standard grades of hardwood lumber. Obviously, if you were a case goods manufacturer buying No. 1 Common lumber, you would obtain little utility from stock in which all of the boards were similar to those illustrated in the 16-foot, No. 1 Common board in Figure 2. However, the board illustrated in Figure 1 would produce a much higher yield in the parts needed. By the same token, the board illustrated in Figure 2 would be excellent for use by the manufac-

PLATE NO. 1

Typical No. 1 and No. 2 Common Boards Showing the Placement of Defects That Class Them As Ripping or Cross Cutting Boards. Figures 1 and 3 Show Boards That Should Be Ripped Before Cross Cutting. Figures 2 and 4 Should Be Cross Cut As the Firat Operation.

Fig. 1.—16′ x 12″ No. 1 Com. —14′ and Over surface measure. 5 cuts permitted. Board contains 192 units, 128 units required in 5 cuts. 140 units actually obtained.

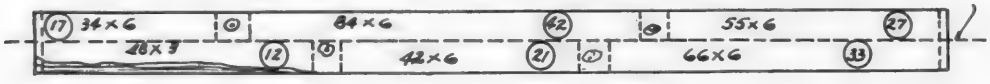


Fig. 2.—16′ x 8″ No. 1 Com. —11′ to 13′ surface measure. 4 cuts permitted. Board contains 128 units. 85 units required in 4 cuts. 91 units obtained in 4 cuts.

Fig. 3.—16′ x 12″ No. 2 Com. —14′ and over surface measure. 7 cuts permitted. Board contains 192 units. 96 units required in 7 cuts. 108 units obtained in 7 cuts.

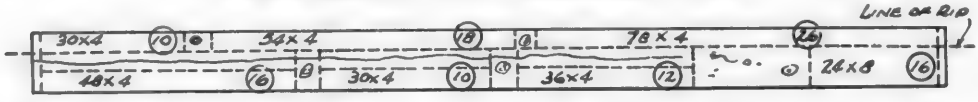
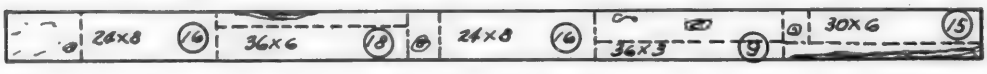


Fig. 4.—16′ x 18″ No. 2 Com. 11′ to 13′ surface measure. 6 cuts permitted. Board contains 128 units. 64 units required in 6 cuts. 74 units obtained in 5 cuts.



turer of chairs, tables and novelties. They would obtain approximately the same ultimate yield from the grade purchased.

The principal factors, that determine the proper grade of lumber from which any set of wood parts should be produced, are length, width and grade of cutting, and the quality of each of these cuttings in relationship to the whole of the raw material required.

There are a few general rules that should govern. One should never purchase No. 2 Common lumber in anything else than a 50 percent clear cutting grade or a No. 2A Common grade, if the parts required must be a clear one face, or clear two faces, or if the length of that part is longer than 30 inches. If the part is to be edge glued for core stock, the maximum length that one could expect to obtain in suitable material would be 43 inches from a No. 2A Common grade of lumber, and this could be obtained only if the proportion of cuttings from 36 to 43 inches in length was but a small proportion of the total footage needed. For the same reason, the maximum length that can safely be obtained from No. 1 Common lumber in producing a clear two sides cutting is 43 inches, or 60 inches for a clear one side cuttings; the 60-inch cutting obtained from a No. 1 Common board will be rather narrow.

Examination of Table 1 will answer the question of minimum cutting sizes. A No. 2 Common board contains a minimum cutting that is 2 feet long by 3 inches wide. A No. 1 Common board contains a cutting 3 feet long by 3 inches wide, or 2 feet long by 4 inches wide.

There is no guess work, but there is need for study or research, if you will, so that the average plant converting lumber may determine for itself the proper grade of lumber that should be used for producing a particular set of parts for a specific item in production.

The initial cost of lumber is very important, and the difference in price between the grades to be considered will often determine the grade to be used. It can be assumed without contradiction that the cost of converting lumber is greater for the lower grades than for the better quality boards, but in most instances the difference in cost is more than offset by the savings in the initial cost of the raw material.

To illustrate, let us assume that kiln dried and delivered to the mill No. 2A Common Poplar has a value of $50.00 and No. 1 Common Poplar a value of $65.00 per thousand feet. Test results have determined that the range of cuttings can be obtained from No. 2A Common with 60 percent utility, or a net material cost of $83.33 per M.b.m. on the other hand, No. 1 Common will produce the same set of parts with 65 percent utility, or a net cost for raw material of $100.00 per M.b.m. The difference in cost is $16.67 per thousand net feet. The governing factor, therefore, must be the difference in labor cost of conversion.

One would immediately say, "How is it possible that there is only a 5 percent difference in utility between a 2A Common grade and a No. 1 Common grade?" It is a perfectly reasonable and logical question.

To answer this question, it is necessary to define utility, or waste, as used in the conversion of rough boards into blank dimension sizes of the finished product. Utility is the volume of finished blank sizes of wood parts that result from the conversion of a given volume of rough lumber into these parts. If we say, therefore, that we have a utility of 60 percent, this would mean that we obtained 600 board feet of parts from 1,000 board feet of rough lumber. The material cost of this 600 feet would be the cost of the 1,000 feet of rough lumber required to produce them.

Expressed in terms of waste, this would mean that 40 percent, or 400 board feet, of lumber was lost in the conversion. We are very much interested in waste, and we talk of "waste utilization." Waste and utility are the two variables whose sum equals the whole. In converting rough lumber into finished products, waste falls into one of two classes, being either fixed or variable waste.

Fixed waste can be measured and accurately determined before the boards are cut. It is composed of end waste resulting from cutting the specific groups of lengths needed in the final finished parts from the standard lengths of 6-, 8-, 10-, 12-, 14-, or 16-foot lumber. This type of waste will not vary with the grade of lumber that is being cut. It will be just as high from Firsts and Seconds as it will be from No. 2A Common. Saw kerf, trimming waste, machine allowances for cutter heads, edging waste resulting from the cutting of standard width boards into standard width parts are all types of fixed waste.

Variable waste cannot be measured accurately. It is that waste caused by the removal of defects inherent in the grade and species of lumber being cut, and will vary in amount, depending upon the requirements for grade of the finished dimension blanks. Edging waste in the cutting of random width hardwoods also will vary, to a large degree, especially in those parts which cannot be glued for width.

It has always been interesting to me, in analyzing the results of numerous waste studies, to find that the relationship of "variable waste" to "fixed waste" is nearly always equal, when the proper grade and length of rough lumber has been selected for the production of a given set of parts.

In the previously cited case it is, therefore, understandable why there is only a 5 percent difference in the utility of the No. 2A Common lumber and the No. 1 Common lumber, when cutting into a range of parts that was suitable for either grade. A large part of this 5 percent variation is caused by defects or "variable waste."

From the above discussion, it can be seen that, when lumber is carefully analyzed and the grades are thoroughly understood, it is really difficult to miss the final utilization that can be expected from rough lumber if waste has been calculated correctly.

How are the best ways to determine waste? The best known means is the weight method, and it is my opinion that few large plants converting hardwood lumber can afford to be without a platform scale, so that rough lumber may be weighed into the mill and the yield and waste measured by successive operations.

By so doing, even saw kerf and that portion of waste going up the dust pipe in the form of shavings can be determined. We have determined our utility figures for many years on this basis. Once safe utility figures have been computed, many plants using the higher grades of lumber will find that there are possibilities for real economy in the utilization of lower grades, in part or in whole, for the manufacture of their finished produce. Dollars spent in the selection of lumber in the yard for specific "end use" are the cheapest dollars that can be spent in most plants using hardwood lumber as a raw material.

Too little consideration has been given to the problem of waste and its correction. If the utility of hardwood lumber could be increased by only 5 percent, by improved channelling and conversion, it would mean the saving of 350 million board feet of hardwood a year based on the current annual production of seven billion board feet. That is more lumber than our company has used in its 52 years of operation. At a value of $50 per thousand feet at the mill, this would mean an annual saving in raw material of $17,500,000 to the wood consuming industry.

Mind you, this saving has nothing to do with other methods of waste utilization. This is simply a matter of "know how," plus common sense, plus simple arithmetic. The Members of this Society can supply the "know how."

Discussion

Mr. M. R. Brundage (Central States Forest Experiment Station): Mr. Dosker has given us a clear, concise presentation of the problem of hardwood common lumber utilization from the viewpoint of wood remanufacturing plants. My observations at such factories throughout the Central States area prompt me to endorse heartily his recommendations for studies in the four phases of the problem, as he has listed them. While the emphasis on the market studies should certainly be on *present usage* of hardwood lumber, it would appear desirable for the investigators not to exclude entirely consideration of possible new uses. Also, they should keep in mind the grades lower than No. 2 Common, which are a headache for the forester, timberland owner, and lumber producer.

As the speaker has said, much work has already been done on the development of hardwood log grades. The Forest Products Laboratory and other organizations have published many data on yields of lumber grades from different species, sizes, and grades of hardwood logs. There is now established an excellent foundation for hardwood log grading, on the basis of which can be conducted the many local studies of lumber grade yields which are needed by industry. The three types of hardwood boards—rip, cross-cut and neutral—should be incorporated in special grades for particular remanufacturing industries. Conversion studies at sawmills should explore the possibilities of deliberately cutting for rip and cross-cut types on the headsaw and the edger. Undoubtedly much can be done by competent sawmill operators toward obtaining more net volume in potential cuttings and better average quality from all kinds of hardwood logs.

Mr. Harold S. Crosby (Northern Hemlock and Hardwood Association): The utilization of low grade hardwoods in lumber, logging and mill by-products is the most important problem in the Northern Hemlock and Hardwood region of Wisconsin and Michigan and Mr. Dosker's paper has brought up a very valuable recommendation to the fabricators of hardwood lumber. It is logical that some boards be ripped and others should be cross cut, in order to get maximum utilization on the cutting grades. Of highest importance in our region in consuming the common grades is the maple flooring industry and their process is one of ripping, because they require the longer lengths.

Mr. Dosker stated that one of the greatest tragedies is the waste incurred in cutting up hardwood lumber into dimensions required. When our sawmills attempt to go beyond the mere manufacture of lumber, that is, taking what the log will produce, this tragedy can become a catastrophe and the shoals of business are strewn with the wrecks of individuals who attempted to make dimension sizes out of hardwoods with the ordinary sawmill and planing-mill equipment. There exists a distinct miscomprehension among a lot of fabricators as to what we can do in a sawmill. Every day we receive through the mail diagrams or samples of small wood part which people want to

buy in quantity and which they assure us we can make easily and cheaply out of our "waste." It is necessary for us to reply to them that the piece they require comes from the finest material produced in the log, from material which we do not "waste."

Mr. Dosker has brought up also the subject of log grades. The Northern Hemlock and Hardwood Manufacturers Association, in cooperation with the Forest Products Laboratory, the OPA and other agencies, a few years ago developed a set of hardwood log grading rules which are now widely used in our territory. I have been attempting to compute the effect of these rules on our own practices with respect to utilization. For instance, we have 6-, 7-, 8-, and 9-foot lengths now admitted in the No. 1 grade. This has been beneficial in increasing the supply of the veneer mills and a few other industries, but logs of these lengths are certainly a pain for a sawmill man. When short clear blocks are eliminated from our sawmill logs, we also get a reduction in quality in the grades we are best able to sell. For instance, such practice reduces the average length of our clear flooring and also the average width and length of our upper grades which are destined for furniture, hammer boards, and other high quality uses.

Please do not misunderstand me, however, because I am speaking from the viewpoint of a sawmill man and not a fabricator. These log grades were intended to classify and provide for the requirements of the several forest products industries, as well as for the information and benefit of the timber producers. They have gone a long way toward accomplishing that purpose.

Mr. Rudolph Willard (Snyder and Willard): In getting around plants which cut up lumber, I am astounded at the large number which do not keep records of their lumber utilization. The weight basis mentioned by Mr. Dosker is extremely accurate and is simple to operate with a minimum of clerical time. Everybody keeps payroll records which give a basis for labor cost records. In most woodworking plants the lumber cost is from two to five times the labor cost. Why watch the small item and let the big item go uncontrolled?

Mr. Dosker's paper shows some clear thinking and utilization, but it is front office thinking. It depends for its effectiveness upon the men out in the shop who run the cut-off and rip saws. One of the best ways to insure effective action by these operators is to put into effect a lumber utilization bonus, or other incentive payment based on reducing the lumber waste. This can be applied to the rough mill foreman or to the operators, or both, depending on the size of the rough mill crew, the personalities involved, and other local conditions. I have seen some remarkable results in waste reduction by incentive pay. If you want a man to do a job, pay him for it.

Mr. Dosker has drawn a distinction between "ripping type" boards and "cutting type" boards. Most rough mills are laid out for only one process. They either cut everything first or else rip everything first. If a rough mill is not too small, there are many economies in having a dual layout so that some stock can be cut first and other stock ripped first. We have found by experience that, where properly applied, these dual rough mill layouts are big money savers.

One factor which has not been mentioned has a big influence on waste in cutting hardwood lumber. In a complex assembled article, such as household furniture, the design and construction of the assembled article and its various parts can effect large savings in waste. The parts should be of such lengths, widths and thicknesses as give an economical cutting bill. This is ordinarily not given nearly enough attention.

Utilization of Low-Grade Softwood Lumber

H. V. Simpson

Executive Vice President, West Coast Lumbermen's Association, Portland, Oregon

War and postwar demand for lumber has made possible the sale of large quantities of No. 3 and lower grades, which in turn has made possible a recovery from the forests' of much low-grade timber previously not used. This conservation can be maintained if the market for lower grades of lumber can be continued. A research program to determine proper use of low-grade lumber is the most important need in the lumber industry today.

I HAVE never known anyone who did not favor conservation. I have known some people, but not many, who have had very practical suggestions as to what to do about it. I have known few people who have had an opportunity to do anything specifically about it.

And yet in the last five or six years more progress has been made in the conservation of our forests than in the entire history of forestry. Brought about, not by brilliant effort of our researchers, not by edicts of our government, not by enlightened planning by our manufacturers, but by economic forces none of us foresaw, planned or influenced.

The war demands for lumber, followed by the heavy postwar demands, have made possible the recovery from our forests of 20 to 25 percent more of the trees than in the prewar years. Note the following comments by the Bureau of Land Management of the Department of Interior:

"As a result of this careful correlation of cruising standards with the market conditions, O. and C. Cruises consistently show timber volumes which can be economically recovered. Comparisons of current cruises with those on the same areas made four and five years ago show them to be 20–25% higher than the earlier cruises. Specifically, the increase is due to the following utilization practices:

1. Taking four 32-foot logs from trees in which only three were considered merchantable a few years ago.
2. Cutting and taking marginal logs from trees which were previously considered unmerchantable.
3. Taking more of the so-called minor species, such as Hemlock, White Fir and Incense Cedar.

"Another illustration of increased utilization is the increase in salvage operations on areas which were previously logged for all the currently merchantable timber. It is difficult to determine the percentage of recoverable increase over the original cruise through salvage operation, but many operators are known to be taking considerable merchantable volume from logged over lands which until recently were considered uneconomical to relog.

"However advantageous the increase in volume, there is one result which may be considered disadvantageous. There is a reduction in the percentage of recovery in the upper grades of lumber and a corresponding increase in the percentage of lower grades. This naturally follows in the average green timber operation because the increased volume is usually in the lower grade logs from the upper part of the tree which produces a small percentage of the upper grades of lumber. In salvage operations, this is not always true, since in the peeler type of stand, high value logs may be recovered from butt logs of trees which were previously considered culls. As a whole, however, the increased recovery usually decreases the average sale price of the logs or the products manufactured from such logs. In many cases, the low grade logs 'are in the red' before reaching the lumber market and the production costs must be carried by the high grade log. As a result, it would be impossible for

many concerns to continue taking much of this class of material from the woods, were it not for other benefits which accrue in the process. More complete utilization leaves the stand in better condition for fire protection and reforestation. It also increases the annual production, thus increasing the life of the operation."

The Forest Service reports similar increases in utilization of their forests. The story from private operators is the same.

Note what this means—20 to 25 percent more products from the same stands. The nation's reserve of mature timber has been increased 20 to 25 percent. This is conservation of the highest order.

How was this increased utilization brought about? Simply by the marketing and use of No. 3 and lower grades of lumber. The tremendous demand has made it possible to sell the lower grades. In the Douglas fir industry, the lower grades developed prewar were eight to ten percent of the cut, now they comprise over 25 percent. In the Douglas fir area probably two billion feet of No. 3 and lower grades are now produced annually; such material will continue to be produced so long as a market is available. So long as this two billion feet can be sold, just so long will our gains in conservation be continued.

I have always felt that one of the major wastes in lumber was in its use. To me it is just as great a waste to use too much lumber of too good a quality on any job as it is to leave usuable wood in the forest. Yet anyone with the slightest knowledge of our usual construction methods knows that, since the beginning of construction on this continent, we have always used too much lumber of too good a quality on nearly every project. This was natural; forests were in surplus; lumber was cheap. Extravagant use of lumber was unavoidable.

Today we face a new situation. Our trees are counted. Lumber will from now on be at a relatively higher price relationship with competing commodities. Proper use of the proper grade and the proper size must be attained. This means economy to the user. It means longer life to our sawmills. It is conservation of the highest order.

What specifically can be done about this? A nearly complete solution can be found by the proper utilization of No. 3 and lower grades in the form in which they are manufactured at the mills, that is, in plank and boards and dimension. Most of this lumber cannot be further refined, because the added costs are prohibitive from a competitive angle and, in addition, few of the mills have facilities for further refinement. It cannot be used for insulation board or alcohol or any of the other proposed by-products, because of the volume involved and also because these by-products should properly be made from slabs, trim and sawdust of which there are available tens of thousands of tons. Clearly the solution is in increasing the use of No. 3 plank, boards and dimension.

We do not necessarily need to find new uses for lumber to find the answer. In prewar years, the No. 3 lumber normally developed was used principally in the manufacturing region of the Northwest, in California, in the Atlantic Seaboard and in some scattered localities across the country. Presumably it was all properly used. In the Northwest, many who are familiar with construction will vehemently defend the use of No. 3, claiming it is more than adequate and will challenge any section of the country to produce better structures regardless of the quality of lumber used.

Others disagree. F.H.A. regulations in some sections prohibit the use of any No. 3 in houses insured by them. Some building codes prohibit its use. Some government specifications do not allow it. In some sections builders are opposed to it, and in other sections distributors will not handle it. There are perhaps as many who are as vehemently opposed to its use as there are those who fervently support it.

There has never been any important study on the use of lumber. Probably there has never been any particular need for such a study. Lumber was in surplus and cheap—why bother? It is true that little is known about the proper use of most lumber. Limited personal experience has been the guide and that this experience has varied is evidenced by the widely varying viewpoints held by so many.

It is now time that we had a look at the use of lumber. Where can No. 3 be properly used? Where should it not be used? Can its use be greatly widened by small changes in grading? Can more of it be utilized if larger than usual sizes are used? Is its major defect lack of strength? or stiffness? or insulation? These and many other questions should be answered.

The Forest Products Laboratory at Madison, Wisconsin, has already shown a sympathetic interest in this problem. The Laboratory has developed a test program using No. 3 Boards and Dimension which when complete should give us some of the answers. Oregon State College is also proceeding on a program which may eventually include use of No. 3 in small farm structures. The State of Washington is tentatively interested in similar research. Much can be learned from a practical field study of the millions of structures already built from lower grades.

I think there is a proper market in this country for all the No. 3 lumber that can be produced. I think this market can be defined, that simple rules for the use of low grades can be developed, that its proper use can be greatly expanded. I think this is the greatest challenge to research in the wood industry today.

The study of utilization of lumber does not afford the glamour of some other phases of wood research, such as is presented by chemistry perhaps, yet it is by far and from all angles the most important problem before us today. Results of lumber utilization research should make possible the continuation of progress in conservation with all that it means in continued prosperity in our lumbering industry. I hope this program will have the active energetic support of your society and its members.

FOREST PRODUCTS RESEARCH SOCIETY

Some Observations Regarding the Status of the Wood-Distillation Industry

Edward Beglinger

Chemist, Forest Products Laboratory,[1] Forest Service, U. S. Department of Agriculture

A marked decrease during the past 20 years in the number of wood-distillation plants was revealed through observations by the U. S. Forest Products Laboratory. The amount of wood consumed has been correspondingly reduced from about 1,000,000 cords per year in 1927 to about 550,000 cords per year at the present time. Competition for raw material with other purchasers is increasing and, further, difficulties exist in the procurement of it because of diminishing supplies near the plants and higher labor costs. Markets have been a continuing problem and are of no less concern now. The sale of charcoal appears restricted to fewer large-tonnage markets, and wider outlets appear necessary in order to insure a satisfactory price level. Of the total amount of wood consumed in the 20 plants of the hardwood-distillation industry, about one-half is used by the eight plants of more modern design. Investigations into continous carbonization, wider markets for charcoal, integration of processes for the recovery of acetic acid and methanol with modified forms of carbonization, and further mechanization of chemical-wood procurement are suggested as possible means of improving the status of the industry.

Introduction

THE wood-distillation industry in the United States is faced with the twin problems of diminishing supplies of raw materials and dwindling markets for its products. Observations by the U. S. Forest Products Laboratory have revealed that despite the use of additional species of wood, made possible through continuing research, it has become increasingly difficult to supply the plants with raw material at a price that will permit profitable operation.

The supply of raw material through the course of years has determined both the location of the plants and the products that they manufacture. In consequence, although similar carbonization methods are employed, the industry is divided into branches; one for the distillation of hardwoods, the other of resinous woods.

Beech, birch, and maple provide the chief sources of raw material for hardwood processing. Large stands of these species occur in a rather wide belt extending roughly from the Central States through Pennsylvania and the New England States. It is within this area that the majority of hardwood-distillation plants are located. "Fatty" longleaf and slash pine stumpwood provide the most suitable source of raw material for resinous-wood processing and restrict plant locations, in general, within areas along the Gulf States.

Although each of these areas was once a source of abundant supply and raw material was both readily accessible and cheap, quite the reverse is true today. Careful forest management is essential as is the promotion of better utilization methods for forest and wood waste, if the plants in these areas are to continue operation. To this end, it is an advantage that the distillation industry can be easily fitted into both practices.

Since roughly 60 to 70 percent of the raw material consists of cull logs and sections, low-grade logs, and slab waste, chemical-wood operations are an aid to good forest management and industrial integration. Along with beech, birch, and maple, considerable amounts of ash, hickory, gum, tupelo, and oak are now used in the hardwood industry, and thus the dwindling supply of traditional species has been materially supplemented. Although good results are obtained with resinous-wood stumps removed from potential forest and agricultural lands, the supplies of such raw material are not perpetuated, since the value of second-growth stumpwood for distillation purposes is questionable.

The industry includes very old and small plants, some of average capacity, and some of more recent design and equipment with largest

[1] Maintained at Madison 5, Wisconsin, in cooperation with the University of Wisconsin.

capacity. During the past 20 years the trend has been toward the elimination of the smaller plants. The margin of profit under the most favorable conditions has always been narrow and offers little protection to the weaker or marginal plants. Mounting wood and labor costs, particularly in recent years, together with highly competitive markets are factors of major concern to the industry at large, but have a more telling effect upon the small plants. Likewise, technological progress over the years has benefited the large plants more than the small ones, and the competitive position of the stronger plants has usually been improved, while plants of smaller capacity have earned decreasing returns and, in some cases, been forced to abandonment.

Observations Regarding Hardwood Distillation

The principal marketable products of the hardwood-distillation industry are acetic acid, methanol, and charcoal. In brief, hardwood processing, as shown in Figure 1, may be regarded as a two-step operation, wherein (1) the wood is predried and carbonized, and (2) the crude liquid products obtained are separated and partially or completely refined as facilities permit. Carbonization is carried out chiefly in the conventional, externally heated ovens, but in one instance in vertical, tube-type retorts. The standard oven operation is by batches and generally uses wood of cord or large-block size. The vertical retorts operate continuously on hogged or waste wood of similar particle size. The reaction heat given off as the wood distills is fully utilized and maintains continuous distillation conditions. Charcoal is obtained as a distillation residue from the ovens and retorts.

The procedure for refining the crude liquor depends primarily upon the available facilities for acetic acid recovery. In the older and, more particularly, the smaller plants, the acid is recovered indirectly as the calcium salt. The larger plants with more modern equipment recover acetic acid directly from the crude liquor, by means of extracting agents and subsequent distillation. Methanol is obtained by batches, when the acetic acid is recovered indirectly, and continuously when it is recovered directly.

On a rated cord basis, the capacity of the hardwood plants has steadily decreased and now is less than half that of 20 years ago. At the beginning of the period 1928–1948, 52 plants were operating with a yearly wood capacity of approximately 950,000 cords. The rated wood capacity of the 20 units now active is approximately 425,00 cords per year. These plants, known to be operating as recently as 1945, are located chiefly in the Northeastern States, the Lake States, and a few in the South Central States.

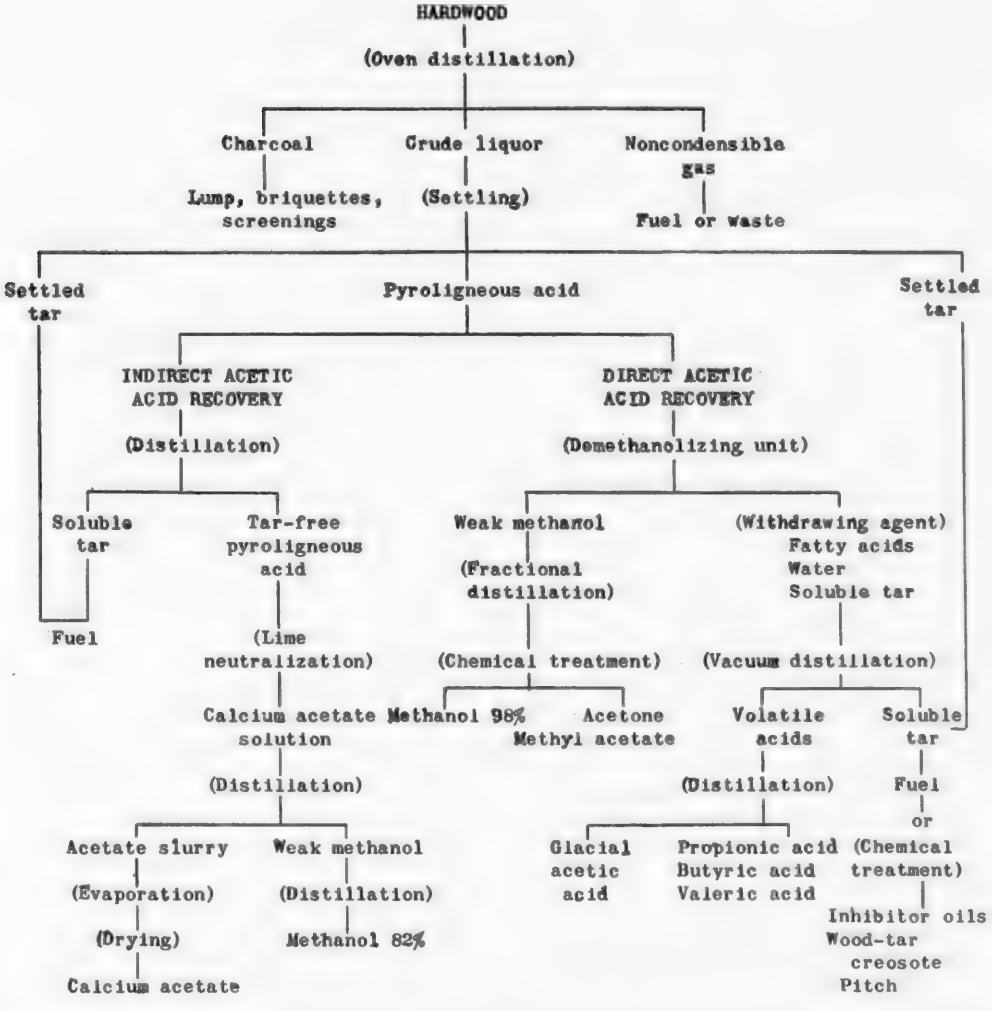
Deviation from traditional refining methods became apparent about 1928, at a time when much of the methanol market was being taken over by synthetic production. The newer methods adopted provided for the production of acid by direct means, with close integration for recovery of methanol continuously. These more efficient refining steps were essential from the standpoint of market and plant protection, and represent the major technological development of the industry from this time on. The wood consumed in the plants using more modern equipment accounts for an increasingly large proportion of the total wood processed. Table 1 shows these estimated amounts over the past 20 years at 10-year intervals.

TABLE 1.—ESTIMATED CONSUMPTION OF WOOD BY HARDWOOD-DISTILLATION PLANTS FROM 1927 TO 1947

Plants	Consumption		
	1927 Cords	1937 Cords	1947 Cords
Entire industry	790, 000	600, 000	490, 000
Direct recovery plants	60, 000	150, 000	270, 000

Both the older type of plant and the more modern processing units are active at the present time, with the older plants numerically stronger. Of the total now in operation, five establishments have capacities of 30 cords or less per day and the others increase in capacity to the three largest, which process 200 cords per day. These three, together with five of approximately 60 cords daily capacity each, are the more advanced units and recover acetic acid directly. Limited capacities of the 12 remaining acetate plants hardly justify the heavy investment that would be required for conversion to the more efficient operating methods. As shown in Table 1, over a period of

Fig. 1.--Procedures commonly applied for the distillation of hardwoods and principal byproducts obtained



20 years new and modernized plants accounted for progressively larger amounts of wood processed each year. In 1927, 1937, and 1947 these amounts were 7.5, 25, and 54 percent of the total consumption of the industry, respectively. Comparatively, industry shrinkage of the total amount of wood consumed was roughly 25 percent in 1937, but in the succeeding 10-year period only 16.5. It is estimated that only 12 to 14 percent and 5 to 6 percent, respectively, of the total amounts of acetic acid and methanol produced in the United States are now obtained from wood distillation. The amounts of these products produced yearly by the acetate plants has decreased correspondingly and now might well be absorbed by the plants that recover the acid directly. Further, the quantities of acetic

acid and methanol produced by both types of plants are largely incidental to the manufacture of charcoal and are relatively unimportant commercially.

In hardwood distillation, charcoal is returned to the plant at a rate of about 1,000 pounds for each cord of wood distilled and represents roughly a 275,000-ton output for the industry in 1947. Rapid removal to suitable markets is essential, and if this is not possible it is generally recognized that plants cannot remain active for any length of time. Reportedly, the demand for charcoal is about equal to production, with the price per ton as of February 16, 1948, at a high level of $39.50 f.o.b. plant. Unfortunately, this comparatively high return represents little more than is required to meet the increased costs of wood, labor, and materials. There is probably little difference between the profit per cord existing now and some five years ago, since in this same period wood costs alone increased from about $5.50 to $11 per cord.

Uses for large tonnages of charcoal have been lost to coke in the metallurgical field, and other carbons likewise have displaced it to a substantial degree in the chemical field. Recent estimates indicate that uses for the largest amounts of charcoal are confined to the domestic fuel, recreational, and several specialty fields. It is possible that these specialty fields may provide greater market opportunities. If so, a proper balance of supply and demand could be expected. Otherwise, with the trend toward diminishing industrial outlets, a further curtailment of production capacity would be inevitable.

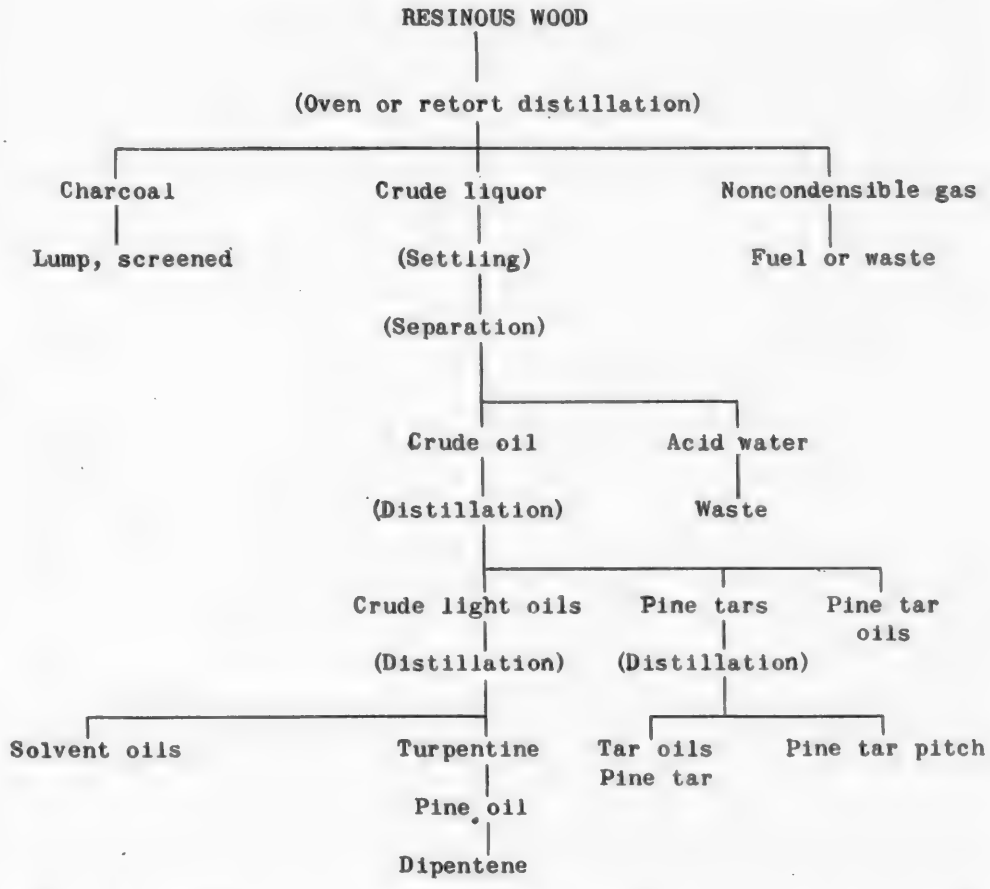
The present status of the industry, as interpreted from rather limited observation and personal contact, is best shown perhaps by the better position of the plants now in existence to produce competitively. This has been achieved, in part through improved processing facilities of these plants, and in part through diminished production of the industry as a whole. The end result appears to be greater stability. Whether this apparent stability of the industry continues will be largely determined by further developments in these two directions.

Observations Regarding Resinous-wood Distillation

The marketable products from the distillation of resinous wood are chiefly turpentine, pine tar, pine oil, a dipentene fraction, and to a less extent, various types of solvent, wood-treating, and specialty oils. Resinous-wood processing, as shown in Figure 2, is similar to that employed for hardwoods with initial carbonization and subsequent refining procedures. The carbonizing equipment varies widely in design, construction, and capacity among the plants. The older, round retorts are rather widely used, along with ovens of large capacity and, in other cases, concrete chambers. Retors with concrete chambers are referred to as "cold-bottom" retorts, since heating of the charge is accomplished with internally heated flues and not by direct bottom heating as applied to the steel retorts and ovens. In general, the end results of the two methods are similar, although higher yields of crude oils have been reported from cold-bottom processing. With the exception of two plants, one of which recovers the crude oil as a basic product and one as a light oil and pine-tar fraction, it is current practice to refine further and obtain additional products. These include turpentine, pine oil, and dipentene from the lighter cuts, together with "solvent" and tar oils, as the refining facilities of the plants permit. Pine-tar wood preservatives are also produced at a number of plants and are prepared in accordance with individual plant formulation.

As has been noted, not all the plants in this industry are in a position either to diversify their products for wider outlets or to meet a specialty market demand, as the case may be. Pine tar has been one of the important products and one of the main sources of revenue to the plants for many years. The older, simply equipped plants can produce marketable grades equally as well as the larger plants of more elaborate design. Both plant types are well represented in the industry, and each is capable of operating at a profit when good markets are available. Markets for tar, however, are becoming tighter with the development of competitive products. Possible lower domestic prices and restricted export shipments are

Fig. 2.--Procedure commonly applied for the distillation of resinous wood and principal byproducts obtained



problems of immediate concern, particularly to the units of limited capacity and products. Charcoal is obtained in about the same bulk amounts per cord of resinous wood as from hardwood distillation and its immediate sale, as in the latter industry, is equally important for profitable operation.

Recent markets for this product have not been encouraging, with respect either to traditionally good domestic outlets or to industrial applications. Resinous-wood and hardwood charcoals have properties that are similar and they may be considered competitive products in the markets. On a tonnage basis, however, returns to the plant from the sale of resinous-wood charcoal based on current market prices, are about one-half the returns from the hardwood charcoal. Adjustments to wider and more diversified outlets and to a more favorable market price appear essential if present production in the industry is to be maintained.

On a cord basis, the wood consumed in the resinous-wood distillation industry has remained fairly constant during the past 15 to 20 years. Within close estimates, the establishments then operating correspond in number

with those now active. Three of the nine plants now operating are located in Louisiana, four in Florida, and two in Georgia. Estimated wood consumption is at the rate of about 120,000 cords per year. Wood procurement problems appear as numerous and as serious as those affecting the hardwood-distillation industry. There is no reason to believe that solution of these problems will be immediately forthcoming. The present status, therefore, is not too clearly defined, but prospects are none too encouraging under the adverse conditions now prevailing.

General

The wood-distillation industry, like so many others today, is confronted with serious problems of raw material, markets, and processing. Because of variations in capacity, methods of processing, and other conditions, no one solution to any of the problems will benefit all plants alike. A number of these same problems have been with the industry for years, while others are of more recent origin. In contributing to the solution or adjustment of some of the problems, the results of individual plant efforts are not always widely known. It would seem in this connection that unified effort would be helpful in overcoming difficulties common to the industry.

Although it is recognized that many of the problems and difficulties that may become apparent to an observer are only too well known to those within the industry itself, the following are some that have appeared in this manner and are likely possibilities toward which research might be profitably directed.

Continuous Carbonization

The more favorable aspects of continuous carbonization include less handling and plant labor, lower fuel costs per cord of wood carbonized, and probably reduction in maintenance charges throughout. Converting resinous wood by this type of processing might be expected to result in economies allowing greater plant return and the possible use of "leaner" wood, when highly resinous stumpwood is no longer available.

Charcoal Properties and Markets

A study of the properties of charcoal and possible correlation of them with end uses of the product may reveal possible means of market promotion and protection.

In general, both hardwood and resinous-wood charcoals are used in the same large-tonnage outlets, but the hardwood charcoals, as a rule, have commanded the higher price. The present price spread might indicate the profitability of further processing of the resinous-wood charcoal, particularly with regard to briquetting and the production of a specialty product.

Byproducts from the Resinous-wood Crude-acid Fraction

Economical recovery of acetic acid and methanol is not now possible. Possibilities toward this end might be greater through integration with continuous or other modified forms of carbonization.

Chemical-wood Procurement

Some progress has been made in applying mechanization methods to chemical-wood procurement. Further studies toward more complete mechanization appear essential, as a means of making more wood readily available, and as a further means of reducing abnormally high wood costs.

Discussion

Mr. Horace E. Hall (Tennessee Products and Chemical Corporation): I note in Mr. Beglinger's paper the statement that beech, birch, and maple provide the chief sources of raw material for hardwood processing. It is interesting to note that oak is now used to the extent of 20 to 25 percent of the total cordage used in the wood-distillation industry.

Mr. A. W. Goos (Cliffs Dow Chemical Company): Mr. Beglinger states that perhaps a modern continuous type retort should be used for distilling resinous wood and that this may help offset the "learner" pine now available. I would like to know if he is aware of any plant in this country, or any foreign plant, that is using a continuous type retort on resinous woods.

Mr. E. Beglinger: There is a plant in Florida, which was operating a retort continuously on resinous wood as recently as December 1947. It was my impression at that time that the operation was considered experimental, although fairly good results were being obtained.

FOREST PRODUCTS RESEARCH SOCIETY

Some Experiments in Sawdust Carbonization

A. W. Goos, M. A. Trepanier and M. K. Johnston
Cliffs Dow Chemical Company, Marquette, Michigan

Results of sawdust carbonization in a Nichols Herreschoff multiple-hearth furnace are given. The relatively low yields of charcoal obtained are explained by laboratory experiments that show the effect of carbonization time on yields.

WHAT to do with the sawdust that accumulates at sawmills has been a problem for many years. Among the many methods devised for utilizing this waste material have been various carbonization processes to produce charcoal and the usual byproducts of wood distillation, acetic acid and methanol.

Many of the carbonization processes have appeared practical and economically sound, but apparently none have been successful. Although numerous plant-scale installations have been made in the past, we are not aware of any that are carbonizing sawdust commercially in this country today. This is strange, in view of the fact that hardwood sawdust is available at many sawmills in large quantities after all fuel requirements have been met.

At the Cliffs Dow plant at Marquette, Michigan, 200 cords of hardwood are carbonized daily. The supply is largely in the form of eight-foot bolts although some slabs and four-foot cordwood are included. All of the wood is reduced by sawing to blocks 12 inches long. The cross section varies greatly but averages about 6 by 8 inches. In this size reduction the sawmill produces about 30 tons of green sawdust per day, or 18 tons on the dry basis. All of this is burned as an auxiliary fuel in the coal-fired boilers. The fuel value may be calculated from the equivalent of coal and this shows a value of $2.43 per ton of green sawdust of 43 percent moisture.

Any chemical utilization of this sawdust therefore would start with a raw material cost of $4.26 per ton of dry wood content. This rather high cost would not apply where there is no need for the sawdust for fuel.

Sawdust Carbonization in Multiple-Hearth Furnace

Recently we had an opportunity to try a multiple-hearth furnace for carbonizing sawdust. The furnace was obtained for another application and it did not seem advisable to devote much time to the sawdust carbonization experiments, but three runs were made under fairly satisfactory conditions.

The furnace used was a 36 inch inside diameter Nichols Herreschoff eight-hearth furnace, arranged for either direct or indirect firing (Figure 1). Indirect, or muffle firing, was used for the sawdust runs and about six gallons per hour of propane fuel was required.

It was not possible to collect the pyroligneous vapors because the system was not gas tight. The hearth and muffle tile work was porous, so that the separation of the hearth space from the muffle space was more theoretical than actual. However, by maintaining more draft on the muffle stacks than on the hearth stacks it was possible to keep the leakage in the direction of the muffles.

The feed to the unit was sawmill sawdust, containing the normal amount of bark and dirt, screened through a ⅜-inch mesh screen. It was predominantly hard maple. Results are given in Table 1.

TABLE 1.—SAWDUST CARBONIZATION IN A NICHOLS HERRESCHOFF FURNACE

Feed—lbs. per hr.	556	443	337
Moisture in feed—percent	29.7	29.6	23.0
Charcoal product—percent of dry feed	21.5	21.0	20.3
*Volatile content of product—percent	15.2	16.8	12.8
Maximum temperature in furnace—deg. C.	537	550	631

*Loss by heating 1 gram sample 7 minutes in covered nickel crucible at 950 deg. C.

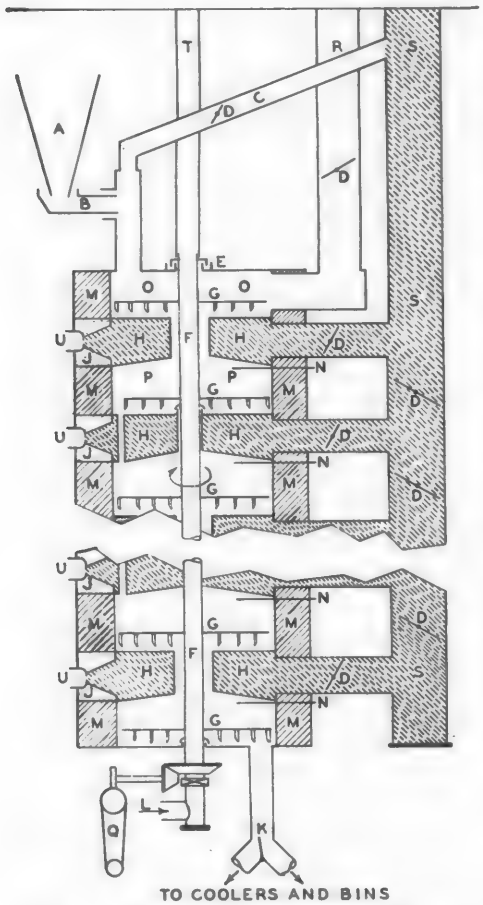


Fig. 1.—Diagram of Nichols Herreschoff Furnace.

LEGEND

A Feeder Hopper
B Vibrator Feed
C Feeder Vent
D Dampers
E Shaft Seal
F Central Shaft
G Rabble Arms
H Muffle
J Burner Block
K Product Valve
L Cooling Air and Steam
M Refractory and Insul. Brick
N Thermocouples
O In Hearth
P Out Hearth
Q Var. Speed Drive
R Hearth Stack
S Muffle Stack
T Shaft Stack
U Burners

The feed rate of 556 pounds per hour was the highest that could be obtained with this pilot-scale equipment. Cost of installation and operation of full-scale equipment of this nature vary inversely with the thruput so that it is generally desirable to operate at a high rate. However, the charcoal yields are low compared with our regular plant yields from blockwood. The plant yield is about 34 percent for charcoal of similar volatile content. The possibility of oxidation and mechanical losses was considered, but it appeared that such losses should be minor and could not account for such a large difference in yields.

It seemed likely that the low yields resulted from the short carbonization time, estimated to be seven to eight minutes, compared with about 18 hours for the plant blockwood. To find out the effect of rate of carbonization on yields, some laboratory experiments were made.

Sawdust Carbonization in the Laboratory

In the laboratory work, maple wood either in the form of plant sawdust or small pieces was predried in an oven at 105 degrees C. This made it easier to obtain rapid carbonization. Drying usually precedes carbonization in large-scale operations also. For example, in the Herreschoff furnace drying occurred in the upper hearths, followed by carbonization in the lower hearths.

A series of four runs was made on plant sawdust, using a stationary laboratory retort. The sawdust was placed in shallow trays in the retort shell, which was electrically heated. The evolved vapors were condensed. A diagram of the apparatus is shown in Figure 2. Table 2 shows the variation of yields with time of carbonization.

TABLE 2.—VARIATION OF YIELDS WITH TIME OF CARBONIZATION OF PLANT SAWDUST

Carbonization time—minutes	15	17	36	122
Maximum retort temperature—deg. C	521	546	513	525
Sawdust charge—grams (dry)	460	570	699	559
Yields in weight percent of charge				
Liquor condensed	39.2	40.5	43.1	41.0
Wood spirits	0.95	1.07	1.25	1.55
Acids as Acetic	3.78	3.74	3.84	4.26
Charcoal	28.1	28.9	31.2	33.0
Volatile content of charcoal—percent	14.7	13.7	16.1	14.2

The results show decreasing yields of charcoal, acetic acid and wood spirits with decreasing carbonization time. The shortest carbonization time that could be obtained with the apparatus used in this series was 15 minutes.

Rapid Carbonization of Small Blocks

In order to get more rapid carbonization, without danger of mechanical loss due to the rapid gas evolution, small blocks of wood were carbonized in ordinary 20-ml. covered nickel crucibles. The crucibles containing the single pieces of dry maple wood were thrust into a hot

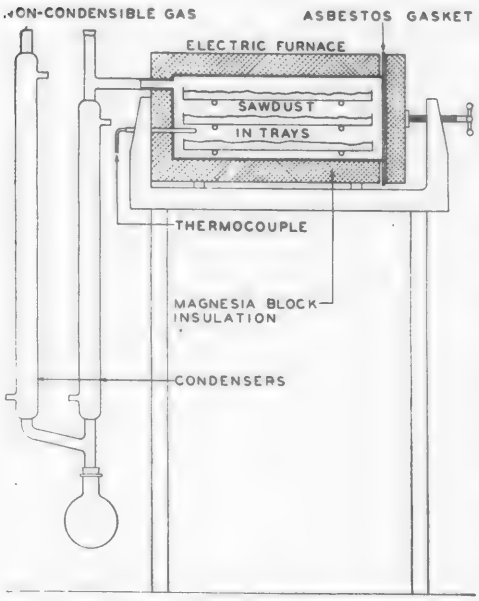


Fig. 2.—Laboratory retort.

muffle and were withdrawn when the vapors stopped burning. Table 3 summarizes the data.

TABLE 3.—RAPID CARBONIZATION OF SMALL WOOD BLOCKS

Weight of blocks—grams	4.64	5.47
Muffle temperature—deg. C.	720	700
Carbonization time—minutes	4.5	4.5
Charcoal yield—percent	18.9	19.1
Volatile content of charcoal—percent	12.5	13.7

The low charcoal yield apparently results from the rapid carbonization, as the volatile content is no lower than many of our plant runs having yields of 34 percent.

Effect of Carbonization Time on Yields

A second laboratory setup that had been used for another problem was available. This permitted charging the wood and cooling the charcoal without chance of oxidation, and the gas evolved could be measured. A diagram of this apparatus is shown in Figure 3.

It was desired to use uniform pieces larger than sawdust particles for this work in order to permit rapid heating and to avoid mechanical losses of the charcoal product. The pieces were obtained by cutting ⅜-inch diameter birch dowel rods into ½ inch lengths. Nine pieces made one charge weighing about five grams, and they rested random fashion on the glass rod valve in the tube above the top of the furnace. The system was flushed with nitrogen while adjusting the furnace to the desired initial temperature. The nitrogen was then stopped and the flushing outlet was closed. Then, by adjusting the glass rod valve, the wood charge was dumped into the hot zone of the furnace.

The fast runs started with the carbonizing zone at 600 degrees C. and in these the gas evolution started immediately and the leveling bulb was manipulated to maintain atmospheric pressure in the system. The slower runs were started at lower temperatures and the temperature was raised gradually to finish off at 600 degrees C. in each case.

An attempt was made in these comparative runs to obtain charcoal products having reasonably low and uniform volatile contents. In the fast runs this required a continuation of the time in the furnace hot zone a few minutes after the main rush of gas was over. This additional time was more a devolatilization period than a carbonization period. To allow for this, the carbonizing time has been arbitrarily defined as the time required to produce 90 percent of the gas evolved.

The charcoal product was cooled by lowering the stainless steel tube and disc support until the charcoal was in the cooling zone. After cooling, it was removed from the bottom and the volatile determinations were then made.

The gas buret system contained acidulated sodium sulfate solution to minimize solubility of the gas in the fluid.

TABLE 4.—EFFECT OF CARBONIZATION TIME ON YIELDS

Carbonization time—minutes	2	21	24	125	390
Initial retort temperature—deg. C.	612	258	235	228	226
Final retort temperature—deg. C.	601	603	603	601	600
Charcoal yield—percent	19.7	23.5	24.5	28.8	30.6
Volatile content of charcoal—percent	14.0	11.6	12.2	12.4	11.1
Charcoal yield calculated to 14.0 volatile	19.7	24.2	25.0	29.4	31.6
Gas yield—ml. per gram of wood	224	159	161	200	211

Data for this series of experiments are given in Table 4 and show that the greatest charcoal yield is obtained with the longest carbonizing time. The charcoal yield decreases as the carbonizing time decreases, and the decrease is

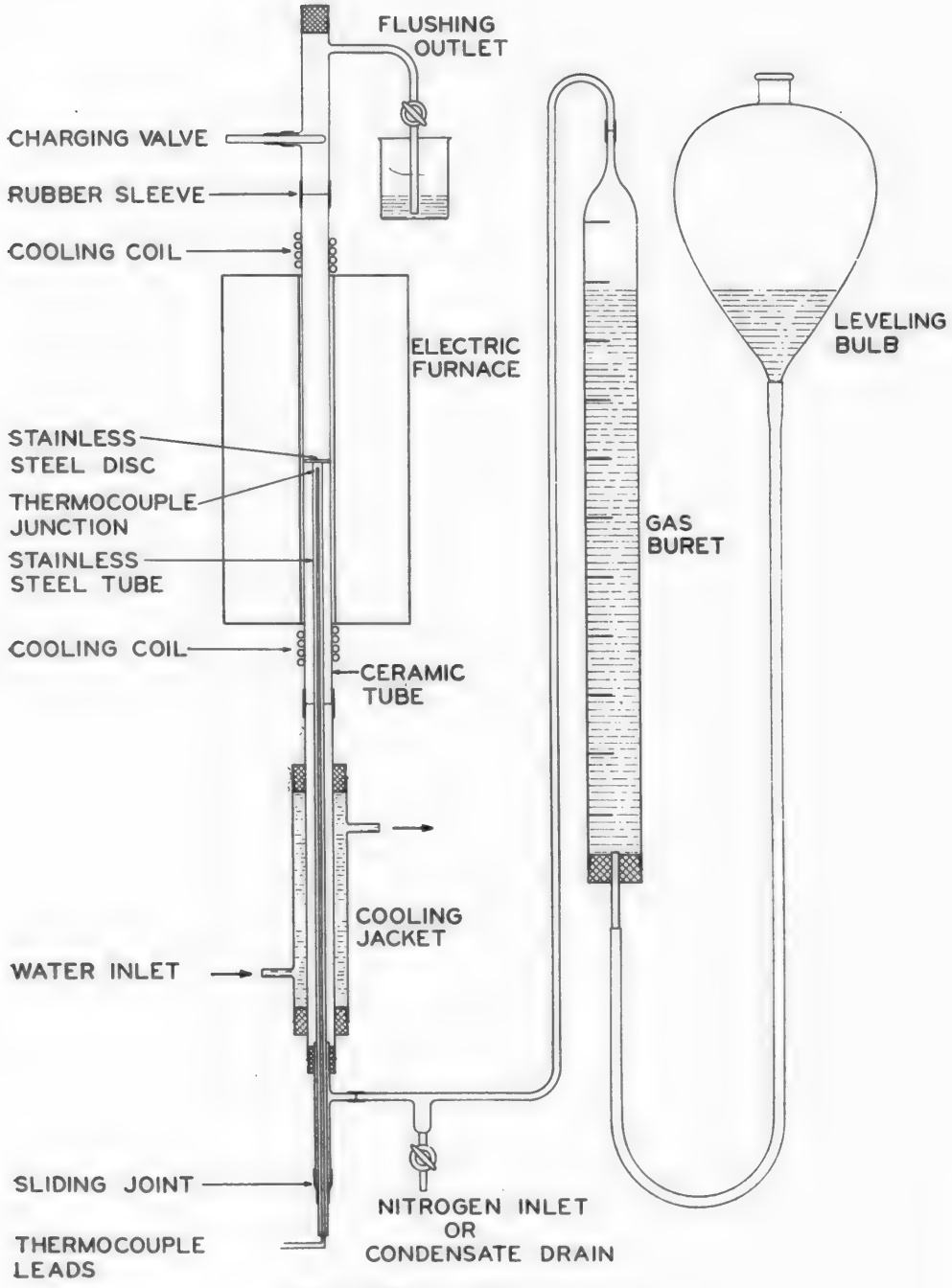


Fig. 3.—Wood carbonizing apparatus.

relatively greater with the shorter times. The charcoal yield at two minutes carbonizing time is only 62.3 percent of the yield at 6.5 hours time.

The gas yield shows a regular decrease with decreasing time of carbonization, except for the shortest time of two minutes. We have no theory to account for the relative increase of gas for the two-minute carbonization. However this run is the only one of the series in which the wood was dropped into the 600 degree C. hot zone. In the other cases, the hot zone started at much lower temperatures and was then raised more or less rapidly to the final 600 degree point. This apparently causes the relatively greater gas evolution.

As an extreme condition, one run was made in which the wood was dropped into the hot zone at 953 degree C. The carbonization was over in less than one minute and the charcoal yield was only 12.75 percent, although it had a normal volatile content of 14.3 percent. This is a remarkably low yield of charcoal under conditions that preclude combustion by air contact and avoid mechanical loss.

Others have reported decreased yields from rapid carbonizations,[1, 2] but we have not found references to very short carbonization periods of the order of a few minutes. Such short-time carbonizations are normal for sawdust or other finely divided wood waste.

It appears from this work that fast carbonization of wood results in low yields of charcoal and by-products. This probably is a significant factor in most sawdust carbonizations and may help to explain why large-scale sawdust carbonization processes have not been successful.

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Discussion

Professor Emanuel Fritz (University of California): I should like to suggest the possibility of using pulverized charcoal as boiler fuel. For some years pulverized bituminous coal has been used in large power installations, much to the benefit of mine-waste utilization.

It may seem ridiculous, since we already burn sawmill wood wastes under boilers in a raw form, to suggest adding several intermediate steps—carbonization and pulverizing. However, pulverized fuel burns more efficiently than raw wood in a dutch-oven furnace and in the manufacture of the charcoal the usual by-products are made available. Since neither the charcoal nor the by-products alone can carry the costs, a combination of high-volume utilization of both might enlarge the field of waste utilization.

Dr. Hereford Garland, of Houghton, Michigan, who is present today, conducted an experiment while a graduate student at the University of California to determine if the charcoal dust would maintain a hot flame. He found that the dust blown into the furnace burned well and fiercely. His results are reported in *The Timberman,* May 1934, p. 19–23.

Professor Hereford Garland (Michigan College of Mining and Technology): Since Professor Fritz has mentioned the subject in his remarks, I should like to comment briefly on my introductory study of the use of charcoal as a pulverized fuel. The work showed that the charcoal is superior for firing in this manner. It has the heat value of coal, but is less dense and can more easily be retained in an air stream. The flame more nearly approaches the character of gas or vapor flames.

The question still to be resolved is whether the yield of by-products in carbonizing, plus the increase in efficiency in combustion, would make this system of firing economically superior to burning the original wood itself.

Animal Feeds From Wood Residue

Elwin E. Harris

Chemist Specialist, Forest Products Laboratory,[1] Forest Service, U. S. Department of Agriculture

The cellulose in unused wood residue from mills or the forest may be converted by chemical means into sugar solutions. This sugar may be concentrated to a thick molasses which may be of value in supplying a carbohydrate feed for livestock.

Wood-sugar molasses is being produced in the pilotplant at the United States Forest Products Laboratory and being sent to many state agricultural colleges and experiment stations for evaluation as stock feed.

Wood sugar may also be used as the source of a yeast that is high in protein and B complex vitamins. This yeast may become a valuable feed supplement for poultry and livestock.

THE high standards of health and living enjoyed in America have depended in part upon an adequate diet that has included a generous proportion of meat. In the past, the nation's ability to grow livestock feeds in abundance has assured a plentiful supply of meat to sustain that diet. Today, however, America is being called upon to supply grain to nations lacking an adequate supply. The amounts it can supply are limited unless it changes its meat diet, or new sources of animal feed that produce meat are developed.

For the most part, beef cattle and sheep graze in grass areas that do not supply sufficient carbohydrate and protein feeds to finish them properly for market. It is therefore necessary for producers of such livestock to have feed shipped in or to ship unfinished stock to areas where such feed is available.

Many livestock producers today find the prices of finishing-feed so high that they cannot afford to feed it to cattle, sheep, and hogs, as freely as formerly. The result is that they are forced to decrease the number of animals to be fed, or shorten the feeding period. The situation could be greatly improved if cheaper animal feed could be found.

A valuable contribution to the solution of these problems may have been found in experiments recently conducted at the U. S. Forest Products Laboratory for the chemical conversion to simple sugar of the carbohydrates in residual wood now unused at sawmills, at woodworking plants, and in the forests, and material in crop residues on the farm. Wood and such farm-crop residues as straw contain 50 to 75 percent carbohydrate in the form of cellulosic materials that are indigestible in their usual form, but which can be converted into digestible sugar by chemical means. Sugar produced in this way does not contain protein, so that, like corn, it must be balanced with protein-rich feeds if it is to be fed to livestock. Its use will, however, conserve the protein present in feed, for this sugar may be used with inorganic materials to grow a protein feed that may be a supplement to other protein feeds.

[1] Maintained at Madison 5, Wisconsin, in cooperation with the University of Wisconsin.

Blackstrap and Beet Molasses

The feeding of blackstrap and beet molasses has set a precedent for feeding highly concentrated sugar solution to cattle, sheep, hogs, horses, and chickens. It is reported[4] that up to 100 million gallons of blackstrap molasses, a byproduct of cane-sugar production, are being fed animals annually in the United States. Byproduct beet molasses is in high demand in the Midwestern States for cattle and sheep feeding. Both of these products contain 50 to 60 percent utilizable carbohydrate material, with the rest being indigestible organic matter, ash, and water. Because the sugar is in a form that is readily absorbed in the animal's digestive system, however, it is, in some instances, rated equal to corn, pound for pound, in nutritive value.

Beet molasses is available only in limited amounts for a short period of the year. It is usually fed by spreading it over beet pulp,

hay, or cut straw. The amount usually fed is four to eight pounds daily per head for fattening cattle, and one to three pounds for fattening sheep. Breeding animals should be given smaller amounts than those being fattened. When fed in this manner, the nutrients of one ton of beet molasses are valued at three-fourths those of an equal amount of corn.

When blaskstrap molasses was fed in too large amounts at the start, some disturbances resulted in the digestive system of feeding stock. If feeding was started slowly and the molasses used as a part of other feed, or given in limited amounts,[8] it was found to be palatable and much relished by farm animals. Quantities suggested to start off with are one pound of molasses per 100 pounds of feed. After stock has become accustomed to molasses, it may be fed from a trough. A common method is to spray the molasses on poor-quality feed or roughage, in order to improve its palatability and get the stock to eat it. It has been found[2] that 9.5 to 21 pounds of molasses can be fed to working mules. Beef cattle may be fed 3 to 9 pounds per head daily.[5]

Feeding practice for molasses follows many different procedures. Molasses is frequently fed from a self-feeder that allows the stock to have all they want. Another method is to spray the molasses on the feed, or to mix it with the feed. This method is frequently used to get stock to eat otherwise unpalatable feed. Molasses is being used in large quantities for prepared feeds sold by stock-feed companies. One such product appears in pellet form. Quantities of molasses equivalent to 5 to 20 percent of the feed are used in this manner.

The sugar content of molasses makes it very valuable as a preservative for grass silage.[1] Many types of grass have their highest protein content and highest food value in their green state. Hay crops past the bloom stage, or those that have been rained on or remain wet, lose food value rapidly. If green, freshly cut grass is placed in a silo with sufficient sugar for a mild lactic-acid fermentation, the silage thus produced retains its food value in the same manner as the starch in corn that undergoes a lactic-acid fermentation that preserves corn silage.

These examples of how beet and blackstrap molasses have been used, point out how valuable sugar can be in a feeding program. At today's prices, which range from $50 to $100 per ton, depending on the distance from the seacoast, blackstrap molasses is considered lower-cost stock feed than corn. Much more of it would be fed if it were available. Large amounts of molasses are going to the chemical industry, where it has higher value.

Data taken from Statistical Abstracts of the United States[7] indicate that the total of both blackstrap and beet molasses available in the past for feeding was about 137 million gallons per year, or 840,000 tons. The total cattle population of the United States in 1944 was 81,760,000, according to the Statistical Abstracts.[6] Assuming that the entire amount of beet and blackstrap molasses were to be fed to these cattle at the rate of three pounds per day, there would be sufficient for a little less than one week's feeding.

When we consider the amounts that could be used by the horses, pigs, sheep, and poultry of the country, the total molasses available is but a small fraction of what might be used. It is evident, therefore, that there is need for an additional source of low-cost carbohydrate feed to supplement the limited supplies of grain and molasses. Wood-sugars may be able to supply it and in so doing provide a profitable market for large tonnages of wood residues.

Experiments with Wood-sugar Molasses

The Forest Products Laboratory experiments[3] have been on the production of a 50 percent sugar solution from wood by hydrolysis of the cellulose with dilute acid, followed by neutralization of the acid and evaporation of the resulting dilute sugar solution. This work indicates that 130 to 200 gallons of molasses containing 50 percent sugar can be produced from a ton of wood waste. Dry, bark-free wood gives about one ton of molasses for each ton of wood.

The feeding of wood sugar to stock is not new. Molasses was produced at the Forest Products Laboratory during World War I by a short hydrolysis of wood that produced the equivalent of 750 to 800 pounds of molasses per ton of wood. This molasses was fed to cattle at the University of Wisconsin and rated an acceptable feed, although quantitative nutritional tests were not conducted. Beginning in 1930,

wood sugar was fed to stock in Germany and considered a satisfactory stock feed for horses, cattle, and pigs. During World War II a hay shortage in Germany, Norway, and Denmark threatened the cattle with starvation. Wood chips were treated with an acid liquor until the cellulose was rendered partially digestible. This product was mixed with urea to supply nitrogen and used as cattle feed.

In order to evaluate molasses produced from various species of American wood and to obtain information on palatability and the nutritional value of wood-sugar molasses, the Forest Products Laboratory is preparing molasses in its experimental pilot plant at Madison, Wisconsin, to be used in feeding tests throughout the country by Agricultural Experiment Stations.

The process used at the Laboratory consists of hogging wood residue to a size that is easily treated. Sawdust and shavings may be mixed with the hogged wood. The laboratory hydrolyzer holds 325 to 400 pounds of wood residue (dry basis). In most cases the wood residue contains from 10 to 50 percent bark and, therefore, the actual wood substance in the hydrolyzer is reduced by that amount. The chips are heated by the introduction of steam until the pressure reaches 50 pounds, when dilute sulfuric acid is introduced continuously at the top and allowed to trickle down through the charge for conversion of the cellulose to sugar and extraction of the sugar. The solution containing the sugar is removed continuously from the bottom.

During the process, the steam pressure is gradually raised to 150 pounds in order to hydrolyze the more resistant cellulose. The solution coming from the hydrolyzer is treated with lime to remove the acid, is filtered, and then evaporated to a 50 percent sugar solution in an efficient evaporator. A 400-pound batch of wood residue containing 25 percent bark will produce about 150 pounds of sugar or 300 pounds of molasses. In addition to the sugar, this solution contains extractives from the wood and mineral matter. The extractives tend to make the molasses bitter to taste. The cost of production in a plant producing 50 tons of molasses per day is estimated to be 7 to 10 cents per gallon.

In order to evaluate the Forest Products Laboratory's molasses for feeding purposes, several agricultural colleges and experimental stations are cooperating by carrying out the feeding tests. Montana State College, at Bozeman, is conducting feeding tests on molasses from lodgepole pine for fattening cattle and sheep. It will be used with rough feed and with mixed grain feeds. Washington State College, at Pullman, used wood molasses produced from Douglas-fir Waste for the preservation of grass silage. Four silos were used, two of which had wood molasses added at the rate of 50 pounds per ton of silage material, and the other two with no preservative. Feeding tests were started December 6, 1947, with five dairy cows on the treated silage and five on the control. Each cow receives 40 pounds of silage daily. Records of weight, production records, and stage of lactation are being kept. Future work is planned to include other types of silage and roughage. Tests on the feeding of chickens indicated wood molasses equal to corn in feeding value and to be free from the laxative effect shown by blackstrap and beet molasses.

The Southern Forest Experiment Station conducted palatability tests by feeding range cattle from a trough with molasses produced from red oak wood, and it reported that the molasses was accepted by the cattle the same as blackstrap molasses. Tests on the feeding of red oak molasses to pigs, in which the molasses was substituted pound for pound of corn at the Mississippi State College, at Starkville, indicated that red oak molasses did not contain the equivalent of corn in food value for pigs. This may be due to the fact that about 35 percent of the sugars in oak molasses are pentose sugars. Several investigators have reported that pentose sugars are not metabolized by pigs. Further tests are being made in which the feeding is on the basis of the glucose content of the oak molasses. Tests on cattle feeding with oak molasses are to be started soon.

Oregon State Agricultural Experiment Station, at Corvallis, will conduct tests on the use of molasses from Douglas-fir for six tests where molasses is substituted for various amounts of barley and tankage. Tests will also be made with dairy heifers to determine palatability as compared to beet or blackstrap molasses, and

to determine nutritive value as well as any undesirable after-effects, such as laxative or caustic effects sometimes shown by blackstrap and beet molasses. One batch of molasses produced from Douglas-fir, in which the acid was only partially neutralized, was fed at the University of Idaho, at Moscow. Cattle did not choose this acidic molasses when other feed to which they were accustomed was available. Subsequently, the acidity was corrected with lime, and further tests will be made.

The University of Wisconsin, at Madison, plans to conduct tests on the feeding of molasses from aspen. These tests will include both the addition of molasses to roughage and as preservative for grass silage. Except for small amounts, which will be sent to various people to let them know the nature of the product, these feeding tests will consume all the molasses the Laboratory is able to make until April. At that time it may be possible to supply molasses for other tests if desired.

Production of Protein from Wood Waste

Experimental work is in progress at the Forest Products Laboratory on the production of a fodder yeast from wood sugars produced from wood by hydrolysis. This yeast contains about 50 percent protein and is high in vitamin B complex vitamins. The usual yield from wood sugar is from 38 to 45 percent, which indicates that about 400 pounds of dry yeast can be prepared from a ton of dry wood. A few feeding tests have indicated that this type of yeast is valuable for chickens, turkeys, and other poultry. Yeast increases the fertility of eggs and improves the general health of the birds. It is also believed that this yeast would be very valuable for the feeding of small pigs and calves. In the past the Forest Products Laboratory's small-scale equipment has supplied yeast for analytical purposes. New equipment is contemplated that will make it possible to supply yeast for a few feeding tests.

Problems concerning yeast production are still to be solved in America, and the Forest Products Laboratory is attempting to learn the answer to these problems. Europe is ahead of the United States in the use of yeast. Germany, in 1943, had capacity to produce about 20,000 tons of yeast from wood sugar per year. The yeast was used as food for both animals and humans. Wood had a much higher value in Germany than in the United States but cost of labor was less. Cost of yeast production in Germany was about five cents per pound, which was very cheap for a protein for human consumption, but which might be expensive for protein to be fed to livestock were it not for the high vitamin B content. The Forest Products Laboratory plans to supply small quantities of yeast to institutions equipped to conduct feeding tests for its evaluation, both for protein and vitamin B content. Arrangements have been made with Washington State College to conduct tests with chickens and turkeys and to make preliminary tests for pig feeding.

Conclusions

A low-cost molasses can be produced from wood. If feeding tests show this molasses to be suitable for stock feeding, unused wood residues can aid in the production of lower-cost meat and dairy products and make possible the release of more grain for human consumption in the United States and for export to other nations. Sugar produced from wood can be used to grow a fodder yeast that is high in protein and vitamin B and that may prove valuable, especially for poultry feeding.

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Discussion

Dr. H. Schwartz (Canadian Forest Products Laboratory): The results of tests on the feeding of wood molasses to animals are not yet available and it cannot be said with certainty to what extent this feed could be used. Indications are, however, that some animals, at least, will thrive on it, despite the fact that it may contain impurities such as lignin and lignin degradation products, mineral matter, and extractives, such as tannins, resin derivatives, etc.

Although the use of wood sugars for animal feed is not new, its commercial application at this time would help to alleviate the world feed-grain situation. It would also assist in resurrecting the wood hydrolysis industry, an industry which received a serious setback when the hydrolysis plant in Oregon, for the production of alcohol from wood sugar solutions, discontinued operating last summer. Wood hydrolysis is of importance to the lumber and wood-using industries as it is one of the few processes which, if commercially applied, can utilize tremendously large volumes of waste wood.

Mr. William J. Baker (Oregon Forest Products Laboratory): Since wood-sugar molasses made from different species are not identical, it is becoming necessary to indicate the kind of wood from which the molasses is produced. The Pacific Northwest, of course, is primarily interested in wood-sugar molasses from Douglas fir. Two experiments are now in progress at the Oregon Agricultural Experiment Station, one applying molasses to low grade hay that is being fed to dairy cows and the other using molasses as a substitute for part of the barley ration in swine feeding.

It is to early to report definite results of these feeding experiments, but preliminary observations indicate that molasses-covered hay is palatable and that no physiological disturbances are apparent in the cows. The swine-feeding experiment indicates that molasses up to 15 percent of the barley ration seems to be acceptable to the animals. A 30-percent substitution is rather unpalatable, the hogs are not gaining weight as they should, and there have been some indications of digestive disturbances. Unpalatability seems to be the principal factor when such a high proportion of molasses is used.

If sufficient material can be obtained, the Oregon Agricultural Experiment Station is contemplating the following tests, using Douglas fir molasses:

(1) as feed for growing turkeys,
(2) as a part of the concentrate mixture for dairy cows,
(3) as feed for laying hens,
(4) as feed for beef cattle,
(5) as feed for lambs,
(6) in silage for dairy cows,
(7) in obtaining a comparison with cane molasses in making grass silage,
(8) in making nutritional studies, using molasses and yeast for animals, particularly the rat, and
(9) in repeating the swine-feeding experiment.

Since the swine-feeding experiment seems to involve palatability, we wonder if unpalatability results from acidity, extractives present, or the character of the sugars in the molasses. Dr. Harris, do you wish to comment on this aspect of the problem?

Dr. E. E. Harris: We have been conducting some tests on the purification of wood hydroly-

zates and find that the sugars in the solution are sweet and in no way associated with the bitter taste. The tannins and perhaps some other extractives contribute to the bitter taste, but since these can be removed by charcoal and the solution is still bitter, most of the bitterness must be due to the acidity and to salts in solution. The acidity can be overcome by adding lime, but the bitterness remains. We have come to the conclusion that the bitterness is due to salts—possibly calcium acetate. This has been verified by naturalization to pH 2.5 which removes most of the sulfuric acid, then evaporating to a 20 percent solution. This evaporation removes both volatile acids and water. It is possible to neutralize the solution and then obtain a solution which is practically free of bitter properties. We are now expecting to get equipment resistant enough to evaporate the solution at the lower pH and then correct the pH after evaporation.

It appears that the hogs in Corvallis are being fed much larger amounts of sugar than they are able to tolerate. It is also more than has been found practical for other forms of sugar. This may account for the necessity of feeding yeast to supply vitamin needed to utilize the large amount. When hogs were fed 15 percent wood molasses, their gain was equal to the control.

TECHNICAL SESSION II

Monday, March 22, 1948, 1:00 P. M.

General Subject: Mechanical Conversion of Wood Waste and Manufacture of Fiber Products

Chairman: William J. Baker, Chief, Industrial Service Section, Oregon Forest Products Laboratory, Corvallis, Oregon *(Former Secretary-Treasurer, FPRS)*

Recorder: Charles B. Hemming, Chief Chemist, U. S. Plywood Corporation, New Rochelle, New York *(Chairman, Abstracting Committee, FPRS)*

FOREST PRODUCTS RESEARCH SOCIETY

Small Wood Briquetting Machine

R. T. Bowling

Chief Engineer, Wood Briquettes, Inc., Lewiston, Idaho

This paper deals with the development of a wood briquetting machine to produce a type of fuel suitable for firing domestic and commercial furnaces with standard stokers. It is the outcome of previous experience in developing larger briquetting machines which comprised the same basic process.

Introduction

THE briquetting of wood is not new, but only in recent years has it been commercialized to any great extent. In the study of the prior art it was evident that most researchers had attempted to use impact and direct pressure. Experiments conducted on both methods readily proved that the desired quality of briquette could not be produced with either, therefore, an entirely new process required development. An understanding of the structure of wood and its action under pressure of one kind or another, with and without heat was the basis upon which the new process was created.

Experiments clearly indicated that pressure, heat, moisture, and cooling would be necessary in the process of making a good wood briquette. Pressure, applied gradually and continuously, was required to reduce the volume of the material and increase its density to that of practically pure wood substance. Heat had to be applied in such a manner as to bring every particle of wood up to approximately the same temperature, in order to bring out the natural binding materials in the wood to bind the particles together. Moisture in sufficient quantity and well distributed throughout the mass of material being pressed was essential to help form the binder. After pressing and heating, the briquette must have a degree of cooling before being released.

It was concluded from experiments, comparable to those of the past,[1] that, if wood material was to be made into a dense self-binding briquette, the material must be pressed in small quantities at one time under great pressure;[2] that the pressure must be continuous and gradual from the time pressure is first applied to the loose material, continuing until it is pressed into its final state.

Briquette-Forming Machine

The wood-briquette machine, as finally developed, consisted of such essential parts as the pressing screw, the tip-forming head, the pressing-screw shaft-bearing housing, the pressing-screw and tipforming-head housing, the dies, and cutting mechanism.

Reference to Figure 1 will identify each of these essential parts, and their functions are herewith described. The pressing screw performs two functions, that of receiving material from the source of supply and of pressing this material through the first stage of compression. Note that the screw is tapered; therefore, as the material is moved forward, it is pressed into a constantly decreasing space. The space directly ahead of the screw and up to the rear side of the tip-forming head is the first stage of compression. It is the function of the pressing screw to keep this space full of tightly compressed material.

The function of the tip-forming head is to take material from the first stage of compression, feed and press it into the second stage of compression. The tip-forming head is designed with a cam face on both its front and rear faces. At the high point of the lead on the rear face, a slot is cut diagonally through the head; this slot enters the front face of the head at the low point of the lead. Since the high point of the lead on the rear face of the head forms the start of one side of the slot through the slot, it is, therefore, a cutting edge by which material may be sliced from the mass of material pressed in the first stage of compression. The forming head is supported by a spindle. The spindle, be-

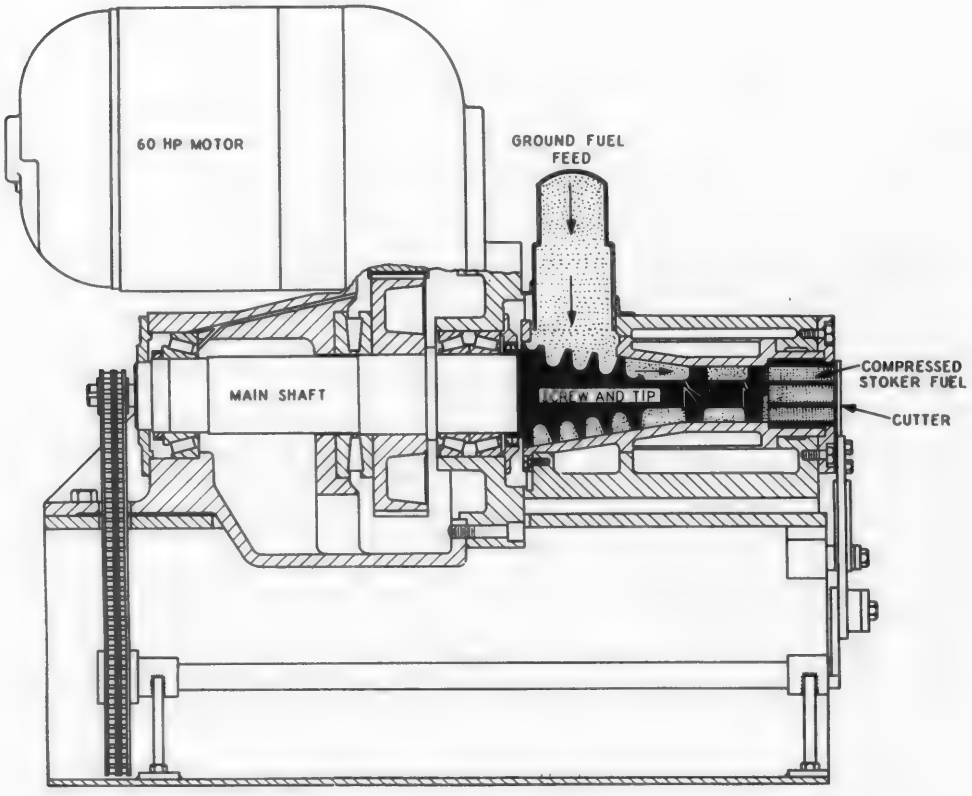

Fig. 1.—Pres-to-Log Stoker-fuel machine.

ing attached to the pressing screw, rotates with the pressing screw. When material has been pressed in the first stage of compression, and is tight against the rear side of head, it is then cut off in a continuous layer and fed through the slot to the front face of the tip-forming head, where it is pressed to its final density by the cam face on the front side of the head and on into the dies, thus forming the size and shape of briquette desired.

The die performs the function of shaping the briquette and is of a length to build up a frictional resistance to the flow of material that will give control of the density of the briquettes being made with a given species of material.

The cutting mechanism is for the purpose of cutting off the briquettes to any desired length as they are extruded from the die.

Size of Briquettes Produced

The standard size of briquette produced on the machine shown in Figure 2 is 4⅛ inches in

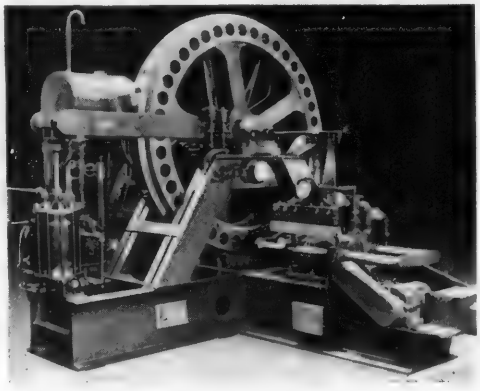

Fig. 2.—Standard briquetting machine.

Fig. 3.—Stoker fuel briquetting machine.

diameter and 12¾ inches long; its weight is eight pounds. Briquettes made by the machine shown in Figure 3 may be of any size from ¼ to 1½ inches in diameter. Figure 4 shows five pieces of 1½ inch diameter being extruded at one time.

In the formation of a briquette, the material is pressed at the rate of seven cubic inches per second. However, this does not mean that seven cubic inches is pressed in one instant, but rather that the material flows at this rate over the tip-forming head which is 4¼ inches in diameter, an area of 14 square inches in one second. Thus extreme pressure is applied to a thin layer of material approximately ⅛-inch thick.

The total pressure that can be applied by the combination of pressing screw and the tip-forming head to an area of 14 square inches is 200,000 pounds, but in normal operation it amounts to approximately 165,000 pounds.

Heat is generated by friction as the material is being pressed and is transferred to the wood particles as they pass over the surfaces of rotating parts of the machine. The maximum tem-

Fig. 4.—Extrusion of five 1½ inch diameter pieces on stoker fuel briquetting machine.

perature the wood will attain in the process in normal operation is about 600 degrees F.

The moisture content of the material may vary from a minimum of two percent to a maximum of ten percent, depending upon the species of material being run and the type of briquette desired.

The average specific gravity of briquettes made by this process is 1.3.

Problems Encountered in Developing Machine

The mechanical problems encountered in the development of this machine were many, *i.e.*, problems of types of materials, strength of materials, new equipment, and controls. The machine is now a combination of electrical, mechanical, and hydraulic equipment.

The essential parts of this machine had to be developed independently of any existing equipment. If briquettes were to be made by the theoretical process we had evolved, as a result of experimenting with old methods, then the various parts must be developed without the assistance of any previous research in connection with this theoretical process.

Since the pressing operation is the most essential in making wood briquettes, it was decided to use a mechanical means rather than steam, pneumatic, or hydraulic pressure for compacting the material. The mechanism adopted is a tapered screw, the object of which is to maintain a continuous pressure on the material. This pressing screw is constructed in a manner similar to many screw conveyors and screw feeding devices. Most screws for handling materials are used solely for conveying and in very few instances are they used also for conveying and compacting.

This feeding and compacting screw, to be used for compacting wood particles to a density suitable for a wood briquette, differs somewhat from the ordinary screw, although the principle is much the same. No set of calculations was or could be correct for the design of a screw for this purpose. About the only way it could be developed was by trial and error. The present screws are 8 inches diameter at the large end, 10¼ inches long and tapered 4 inches per foot of diameter. The lead and depth of thread vary with the type and specie of wood being pressed; for example, white pine requires a 2-inch lead and 1¼-inch depth of thread. The angle of all threads, regardless of pitch, is 15 degrees. All threads are cut right hand; consequently, for them to press material forward they must rotate in the counter-clockwise direction. Material used to make pressing screws is S.A.E. 3140 chrome nickel. The entire surface of the screw from the small end and back two threads is surfaced with No. 1 Stellite or other hard-surfacing material.

Results of Compressing Material

The ratio of compression of the material made into a wood briquette is approximately 10 to 1. About 60 percent of the total compression takes place in the pressing screw and space ahead of the screw which goes to make up the first stage of compression. The remainder of the compression is accomplished with the tip-forming head.

It has been explained that wood is an elastic, resilient material. Therefore, when such material is forced through a tapered cylinder by the screw, it decreases in volume and increases in density and, consequently, expands against the side walls of the cylinder, thereby creating a frictional resistance to the rotating motion of the screw and the forward flow of material through the screw. From this, it is evident that

the screw must be designed to compress the material to the desired density only; otherwise, the frictional load may become so great that material in the screw would rotate at the same speed as the screw and would fail to feed material forward as intended. A great amount of experimental work was required to determine the length of screw, amount of taper, pitch of threads, angle of threads, etc., to make the screw feed and press the desired quantity of material to the required density. All the problems involved in obtaining this correct feed did not concern the screw alone, but also the cylinder in which the screw revolves. This cylinder must be ribbed or rifled to prevent the material from turning with the screw. This was accomplished by grooving the walls of the cylinder for the length of the screw. The space ahead of the screw, between the end of the screw and the rear face of the tip forming head, was ribbed by electric-welding Stellite to the surface of the cylinder. This effectively prevents material from turning with the screw.

This pressing screw is supported on a heavy shaft, the shaft in turn being mounted on two radial bearings. Between these two radial bearings is located a thrust bearing to take the thrust loads of the pressing screw. This thrust bearing was one of the most troublesome parts of the machine. After many bearing failures, a vertical tapered roller thrust bearing solved the problem and is now standard equipment. The pressing screw is removable from its supporting shaft, as it must be repaired occasionally because of the abrasive nature of the material being pressed.

The development of the tip-forming head was also a matter of experimentation. The object of this head is to transpose partially compressed material to a second stage of compression, without loss of compression or interference with the constant flow of material, and to press the material, during the second stage of compression, to its final density.

The requirement of hardening, or hard-surfacing this tip-forming head to withstand abrasion, was one of the most difficult problems. Many experiments were required to determine the shape of the cams on both sides of the head and the size and shape of the slot through the head, as well as size and length of spindle of the tip head. In the development of this head, practically all known methods of treating steels for hardening were tried. The desired hardness could be obtained, but could not be maintained when placed in operation. Heat developed by friction in pressing the material would soon draw the temper of the steel.

The alternative to heat-treating was the application of some type of hard-surfacing material. Several such materials are available and the method of their application to steel is well known. In the application of these hard-surfacing materials with the acetylene torch, there is danger of overheating or burning the metal to which the hard-surfacing material is being applied. This was overcome, insofar as application to the tip-forming head was concerned, by preheating the entire head before the hard-surfacing operation. After the tip head and spindle is hard-surfaced, it is ground to size by special grinding equipment developed for this purpose only.

The tip-forming head is removable from the pressing screw, since it receives more wear than any other part of the machine. A tip head will ordinarily make 400 to 600 tons of briquettes without repairs. Usually several repairs are made before the tip is useless. It is not unusual for a tip-forming head to make a total of 750,000, or 3,000 tons, of briquettes.

The cylinder in which the pressing screw and tip-forming head rotate is designated as the screw housing and cone liner. The cone liner is the part in which the pressing screw and tip-forming head actually work. This liner is removable from the housing, as it is one of the parts of the machine which require replacement in relation to the quantity of briquettes produced. This liner is hard surfaced in the same manner as the pressing screw and tip-forming head.

The dies in which briquettes are pressed for cooling are made of 18-8 stainless steel. Experience indicated that these dies must be of a noncorrosive material and one with a low coefficient of friction. The inside dimensions of the dies is controlled by the species of wood material being briquetted. With some species, the bore of the die may be straight. In others

the bore may be tapered as much as 0.040 inch in the die length.

The total connected load of the machine is from 60 to 65¾ H.P. A total of 65 kilowatt hours is required to make one ton of briquettes. Capacity of machine is 10 to 12 tons of briquettes per day of 24 hours.

Plants for Making Briquettes

A briquette machine plant requires other equipment than the briquette machine only. Usually, buildings or space in an existing woodworking plant are available to install a briquette machine, but auxiliary equipment such as conveyors, grinders, and fuel storage bins must be provided. The cost of making briquettes varies with the cost of labor, power, number of machines being operated, and other factors in any given locality.

Briquettes have been made of practically all common species of wood. All of them make good briquettes with the proper adjustment of pressing screws and tips. Briquettes have also been made from a great variety of fibrous and non-fibrous materials other than wood, such as wheat and pea straw, alfalfa, sugar-beet pulp, bagasse, almond shells, peanut shells, sunflower seeds, flax straw, peat moss, common salt, and many others.

These machines are now in operation in many sections of the United States and in Canada, South America, and South Africa.

Discussion

Professor E. George Stern (Virginia Polytechnic Institute): The design of the briquette machine may not make it advisable to use general wood waste from furniture plants containing soil and dirt adhering to the bark, grit from the sanding machines, and metal inclusions of a general nature. Since only dry wood waste can be used, provided special drying equipment for waste is not installed, these limitations may leave a comparatively small amount of furniture-plant waste from a limited number of machines for manufacture of briquettes. Furthermore, the waste most suitable for this manufacture is most desirable for use in wood-waste cores which may not be a by-product, as the briquette would be, but part of the principal production item of the furniture plant. Thus, the manufacture of briquettes for utilization of the waste of even large furniture plants may not be as worthwhile as the production of other molded items.

Mr. W. G. Raoul (Cavalier Corporation): I have had no experience with briquetting machines, but I was interested in the *reduction of volume* of waste wood which apparently can be achieved. Many furniture and dimension stock plants have a good market for scrap wood in the winter, but cannot sell it in summer, and have no space to store it. Kindling wood is very difficult to handle. It occupies enormous volume. The briquetting machine reduces this waste to a specific gravity of 1.3. I should like to know the specific gravity of a pile of the small size briquettes, and of stacked "Presto Logs." The gain may be great enough to provide rather extensive storage during the warm part of the year.

Special Machines For Utilization of Waste Slabs For Glued Core Stock

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The manufacture of lumber cores from slab lumber has led to the development of many special labor-saving machines. Without these machines, it would be unprofitable to use slab lumber, due to the problem of handling the multitude of small pieces produced from slabs. Because the machines and the process are so closely related, the author has described them both in the sequence in which the stock is carried through the process.

Introduction

THIS paper deals with the utilization of slab lumber in the manufacture of lumber cores for use in making plywood, and particularly with the special machines required to reduce the slabs to usable core strips. In the interest of timber conservation, it might be stated that approximately one cord of slabs is produced from the logs required to yield 1000 bd. ft. of rough and green lumber. Considering that in the United States there are sawn 35 billion bd. ft. of lumber yearly, there are therefore produced at least 35 million cords of slabs per year. This would total 70 million tons and would require two million railroad cars if transported. By re-working slabs into core strips, it is possible to add an additional 20 percent to the usable lumber obtained from the rough log. This figure would vary depending upon the dimensions of the finished product and the amount of handling permissable in calculating cost.

Several industries other than the plywood industry have used slabs to obtain small dimension lumber. Some of the larger lumber mills re-work slabs to produce some types of narrow flooring; also, box mills use lumber from slabs in the manufacture of various types of boxes and shooks. During the last war, there was a scarcity of labor to cut pulpwood, and several pulp mills turned to slabs for the production of pulp. The many thousands of portable sawmills are not equipped to re-work slabs into usable lumber, nor would it be economically sound for them to attempt it due to the amount of machinery and handling required.

Hence, this operation is more economically performed by centrally located manufacturing plants, that can profitably work and use lumber of small dimensions, and are located in a timber-producing area in which they can obtain slabs from ground mills located in the vicinity. The chief problem in using slabs for lumber is to find a use for the random lengths and widths produced. The thickness of the boards is limited in most cases to $1\frac{1}{8}$ inches, while the widths will vary in almost every board from one inch up to the capacity of the saw, and the lengths will run from two feet to the full length of the slabs. Further, all boards will be tapered and will have varying amounts of wane on both edges. On account of these variations, the highest recovery is obtained only when slab lumber is produced to the smallest possible dimensions permitted by the end product. The manufacture of strip lumber cores for use in plywood adapts itself exceedingly well to the use of slab lumber. By using dressed lumber, $\frac{7}{8}$ inch thick, it is possible to cut strips in lengths of four inches up to the length of the panel and in widths from $\frac{5}{8}$ to $1\frac{1}{8}$ inch or whatever width is needed to produce panels of the desired thickness.

Reducing Slabs to Usable Lumber

One of the most satisfactory methods of securing a steady supply of slabs is the use of an independent contractor with a sufficient number of trucks who contacts the various ground mills

and arranges for the purchase and delivery of the slabs.

It is desirable to feed the slabs directly to the sawmill from the truck which delivers them to the plant. However, due to the impracticability of scheduling deliveries, it is usually impossible to do this and means must be provided for keeping a stock pile of slabs convenient to the mill. If the mill is located so that a storage space cannot be provided on a level with the saw, a belt conveyor may be used to carry the slabs from ground level to the main floor of the mill. The conveyor should have an automatic means of control, so that it will be unnecessary for the sawyer to signal to the men loading the conveyor when slabs are required. This can be done by a simple contact switch and permits the sawyer to take the slabs as he needs them, while the only duty of the men feeding the conveyor is to keep it supplied with slabs.

To make the entire operation of re-working slabs profitable, it is necessary to reduce handling of slabs, lumber, and waste to an absolute minimum. The slabs, as previously mentioned, are easily fed to the mill on a belt conveyor, while a system of roller conveyors may be used in a straight line through the mill and to the kiln cars to carry the slabs and lumber. It is also advantageous to locate the slab re-saw in the second story of a building, to make use of gravity in discharging the tremendous amount of waste produced. Openings in the floor should be provided at the slab re-saw and swing cut-off saws, so that the waste may be discharged from where it is produced directly into a hog located at ground level.

Slabs are usually tapered in thickness from one end to the other, with the result that a certain part of the slab is too thin to produce lumber. In feeding the entire length through the slab re-saw, the saw would run idle about half the time. To eliminate this, a swing cut-off saw is installed over the roller conveyor at some convenient point before the slabs are delivered to the slab re-saw. The swing cut-off saw removes the thin section of the slab and the operator discharges the waste pieces into the hog. Additional waste sections will show up when the lumber is discharged from the slab re-saw, and these are cut out by another swing cut-off saw also located over the roller conveyor, so that only boards of usable length are finally delivered to the kiln trucks.

The re-sawing of slabs can be accomplished by either a circular or a band re-saw. The thin kerf produced by a band re-saw is advantageous only when the slabs are thick enough to produce more than one board. With the general run of slabs producing only one board, a circular saw is adequate since the increased thickness of kerf comes from the waste. Circular saws are more easily maintained and operated and have been found adequate for the purpose. These saws are usually constructed with a bed and an adjustable rear fence, against which the slabs are held and fed by spiked rolls driven from the saw mandrel. By this means, the slabs are carried with faces vertical past the circular saw at approximately 60 lineal feet per minute. In re-working slabs to produce strip lumber for cores, various thicknesses of boards have been cut, in an attempt to determine a balance point between the greater amount of yield obtained by cutting thin boards and the increasing costs of handling the thinner boards. It has been found that cutting lumber 1⅛ inches thick when green is the most profitable.

With the slab re-saw located well above ground, it is possible to use a system of gravity conveyors to carry the lumber directly to the kiln trucks, on which it is loaded by hand. An automatic means of loading would be helpful, but so far no practicable means of automatic loading has been devised, due to the varying widths and lengths of the lumber. The operation can be speeded up by delivering the lumber in a position convenient to the men stacking the kiln cars.

The accompanying flow diagram of stock from the dry kiln through the core press shows the arrangement of the various machines (Figure 1).

Preparation of Core Strips

The operation of reducing the various widths and lengths of slab lumber to usable dimensions starts when it is received from the dry kiln. The first operation is to pass the rough lumber through a conventional double-surface planer. Here great care must be taken to plane the lumber to accurate sizes, the tolerance for

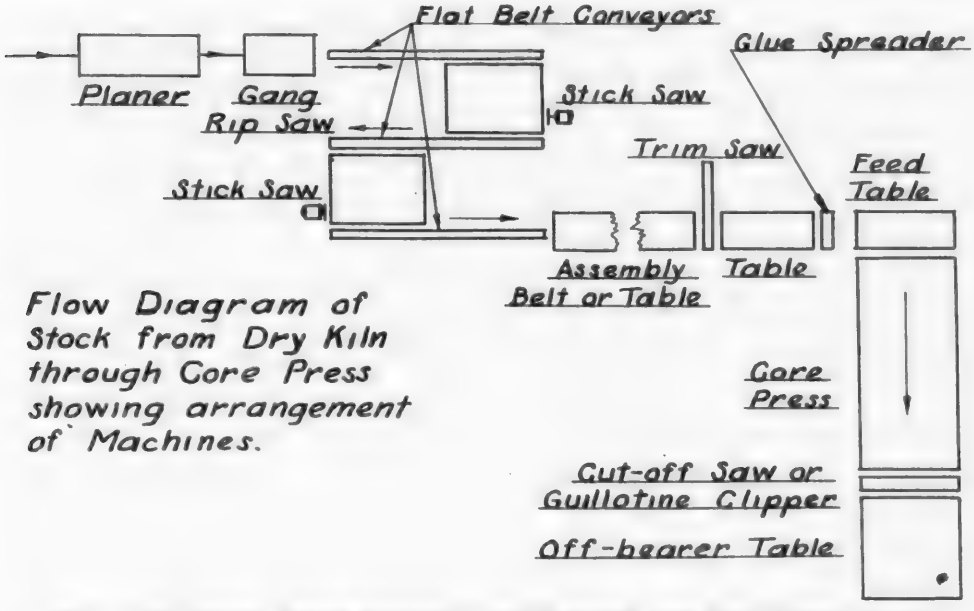

Fig. 1.—Flow diagram, showing movement of stock in utilizing waste slabs for glued core stock.

which should not exceed 0.003 inch. This is necessary when using the lumber for strip cores, which are also known in the trade as stave cores or block cores, due to the fact that the planed surfaces will eventually form the glue lines and any unevenness in thickness between strips will result in uneven pressure when the strips are placed in the core press.

The ripping of the boards into strips of the required thicknesses is another operation which must be performed with the utmost care and accuracy and is usually done by a heavy duty gang rip-saw. These saws are usually of the circular type with several saws mounted on one mandrel and separated by space collars. Various sets of collars of different thicknesses are used to regulate the thicknesses of the cut strips. Swaged tooth saws are well adapted to the ripping, provided that they are properly filed so that the teeth are uniform and of the proper width. Due to the fact that the saws are separated by solid collars, any variation in the width of the teeth would be reflected by a variation in the width of the strips. Tolerances in the width of the teeth should not exceed 0.010 inch. These saws employ rolls to feed the stock and, while a chain feed would be more desirable, the difficulty of adjusting the chains for the varying widths of cuts has so far made their use impractical.

A majority of the strips coming from the rip-saw will be clear and ready for use. The remainder of them will have either knots, which require cutting out, or frequently tapered ends which will have to be squared. This can be done with a small table saw, but the excessive handling has lead to the development of a more efficient system. In this system the strips are discouraged from the rip saw to a flat conveyor belt, from which they are deflected by a baffle to a specially designed stick saw in which one end is trimmed. The stock is then automatically placed on another flat belt from which, in turn, it is again delivered into a second stick saw so that the other end may be trimmed. The stock is next automatically placed on a third belt which discharges to the assembly table.

The stick saw is comprised of a multitude of slats fastened to chains on 1½ inch centers, the slats being about 9 feet long or approximately equal to the average length of sticks. The stock falls onto the slats and one operator places the stock between the slats and positions them by means of an indicator for the cut. Slats and chains carry the stock past a small circular saw which cuts off the defec-

tive ends and allows the scrap to fall into any convenient trash-disposal system. The sound stock remains in the slats until they pass the sprockets, when it automatically falls out and on a conveyor belt. The advantage of this type saw is that the operator does nothing except place the stock in position and does not have to handle the stock after the cut is made. An experienced operator can handle about 80 pieces per minute in this manner. This system also makes it unnecessary to square the ends of the lumber after it is discharged from the planer and before it is fed into the gang rip saw, thereby permitting the lumber to be fed directly from the planer to the gang rip saw with one or two less operators.

An assembly table is required, so that the strips may be assembled with the planed surfaces exposed for gluing and to permit staggering of the joints. The assembly table may be a plain stationary table preceding the glue spreader, or a wide slow-moving flat conveyor belt, depending upon the volume handled.

Gluing and Pressing

The assembled stock is taken in batches, usually about 12 inches wide, and passed through a rubber-roll glue spreader, which coats one dressed side of the strip with quick-setting synthetic resin. It is desirable to mix some color in the liquid resin so that the glued side can easily be distinguished. This assists the operators when they given the sticks a quarter turn before feeding them into the lumber core press. A vertical glue spreader, which would place the glue on the strips in the position which they will finally take in the core, would be very beneficial but, so far, a machine of this type has not been available. Its use would eliminate the labor involved in giving each stick a quarter turn.

The manufacture of lumber-core presses has grown by leaps and bounds since the first experimental units was manufactured and installed in 1940. This press used steam-heated platens to polymerize the glue and proved very satisfactory. There are now several machines available which use the principle of high-frequency dielectric heating. This permits setting the glue in much shorter time, with the result that the entire press may be much smaller and will handle larger quantities of stock. The lumber cores are usually held under pressure and slowly and continuously fed through the steam-heated presses, but in the high-frequency machines the cores are usually cured in batches or one core at a time, this being possible due to the increased speed of dielectric heating. Any type of lumber core press depends for its success on the use of synthetic resins, which set in a matter of minutes or seconds depending on whether steam or dielectric heating is used.

One of the early lumber-core presses which is still in use consists of a pair of steam-heated platens, one below and one above the stock, and approximately 100 inches wide by 9 feet long. The upper platen is adjustable to the different thicknesses of stock. At each end of the platens is a system of steel pressure bars held down by springs and adjustable. The glued strips are placed on steel rails and forced under the pressure bars by a ram or knocker-type feed mechanism. As the stock reaches the pressure bars at the discharge end of the machine, it is held back by the friction of the bars, so that it is continuously held under lateral pressure by the pressure bars at the infeed and outfeed ends. This, with the heat from the platens, sets the glue. More modern machines have now been developed which use a series of chains at the infeed and outfeed ends to accomplish the same purpose.

Another type of lumber-core press which appeared to be very efficient in the production of cores made from narrow strips was produced in Germany before the war, but as far as is known has never been introduced in the United States. This machine did not use glue, but held the strips together by sawing grooves across the body of the strips and forcing strings into the grooves while the strips were held together under pressure. The strings held the strips together very tightly and the product of this machine was very suitable for the manufacture of lumber-core plywood where the edges were not left exposed.

The strips going into the lumber-core press are trimmed to regulate the length of the core, while the width can be regulated either by putting in unglued sticks or by using a traveling cut-off saw after the stock is discharged from

the lumber-core press. A heavy duty guillotine clipper may be substituted for the traveling cut-off saw, if a means of interlocking the press-feed mechanism with the clipper is provided so that the clipper will not make a stroke while the press is feeding. After the cores are delivered from the lumber-core press, they are stacked for cooling and final polymerization of the glue. The final operation is to pass the cores through a single-surface planer and alternately dress both sides. Here again accurate thickness must be maintained to eliminate variation in thickness of the panels after the veneer has been applied.

Yields of Cores From Slabs

Accurate records kept over a period of several months disclose that one cord of slabs has yielded an average of 141 square feet of finished cores, ranging in thickness from 5/8 to 1-1/16 inches. The cost of converting a cord of slabs into cores has been $3.88, and this cost could be reduced considerably by more efficient methods. A single unit mill, converting about 45 cords of slabs daily, produces a quantity of cores which would require 10,000 bd. ft. of lumber per day, or about 2½ million bd. ft. of lumber per year. Considering that the average growth of Southeastern states timberland is about 200 bd. ft. per acre per year, 12,500 acres of trees would be required to produce enough lumber for the production of the same footage as cores which are now being produced from 45 cords of slabs per day. From this standpoint alone, more thought should be given to the utilization of slabs. There is no question that this operation can be performed satisfactorily and profitably, if full advantage is taken of the recently developed labor-saving machinery and if the flow of materials is planned so as to reduce handling to the absolute minimum.

Discussion

Mr. R. A. Hertzler (Southeastern Forest Experiment Station): Earlier in this meeting someone said that the utilization of waste is like the weather—everyone talks about it, but few do anything about it. I can assure you that Mr. Colucci is doing something about waste wood and that he is doing an excellent job of using slabs for glued core stock. I saw his operation and was impressed by its efficiency.

Mr. Colucci states that, "The average growth of Southeastern states timberland is about 200 bd. ft. per acre per year," and that at this rate of growth 12,500 acres of trees would be required to supply the wood for the cores now being produced from 45 cords of slabs per day. Our forest survey figures show that the average growth of sawtimber, both pine and hardwoods, on commercial forest land is only about 112 bd. ft. per acre. This is the growth of timber that is now used for commercial operations. At this rate of growth about 25,000 acres of trees would be required. But this land is capable of growing twice as much as Mr. Colucci indicates, or around 400 bd. ft. per acre per year, if given reasonable forest management, and then only 6,250 acres of trees would be required. I happen to know that Mr. Colucci is managing his land to grow timber, a further tribute to his interest in conservation and in good business practices.

The significance of this system of utilizing slabs is that waste wood often can be put to commercial use for marketable products. The feasibility of such utilization depends in large measure upon the ingenuity and inventive ability of the operator, plus his conscientious effort to do something rather than just talk about it. Not all operators have these qualities in the same degree as does Mr. Colucci.

Mr. S. O. Jones (Nelson Electric Manufacturing Company): From the excellent paper by Mr. Colucci and the other comments from the floor, it is apparent that Mr. Colucci is making money from a process in which many others have gone broke. The reason for this should be of vital interest to any observer. You will notice from his paper the attention given to his methods of handling material, and herein apparently is his key to success. Throughout his process, Mr. Colucci uses mechanical handling methods. This is simply another example of the truism that handling cost quite frequently means the difference between profit and loss. The best way to cut handling costs is to cut the handling. The performance record at Mr. Colucci's plant is convincing evidence of what can be accomplished by mechanical handling.

Interior Trim From Wood Waste

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The manufacture of molded interior trim from wood waste is an outlet for the waste wood produced by a manufacturer of face veneer. This process makes possible the use of cabinet woods as interior trim in homes and buildings, replacing the conventional painted or stained woodwork. Molded interior trim consists of an exterior face of the desired wood and a core of waste wood. The process is economical only for a face-veneer manufacturer.

Introduction

WASTE wood utilization for a manufacturer of face veneer presents a problem which is different from that of many basic wood-using industries. The waste of such a mill roughly consists of 6 percent bark, 16 percent sawdust, and 78 percent slabs and veneer waste. All of the wood is green, having an average moisture content of 63 percent (dry-weight basis), and is derived from very high-priced hardwood hogs and flitches. The problem has been to develop a product which will use all of the waste wood produced by this veneer mill and, if possible, also utilize some of the mill's primary product, face veneer. This new product must be one which will give the waste a higher value than it has for fuel.

From the beginning, it was felt that the product to be developed must be one that could be manufactured in large quantities of the same identical item and, at the same time, obtain any needed variety by changing the species of wood used as the exposed veneer face. The manufacture of flat panels, using a waste-wood core and veneer faces, was not deemed practical. However, the possibility of molding a product having a core of waste wood and a curved veneer surface presented itself as a solution to this problem. A product of this type that could be consumed in great volume is interior trim for houses and other buildings.

Almost all homes have fine furniture, little of which is painted to hide the natural figure and beauty of the wood. But in these same homes, with but few exceptions, the woodwork is painted or stained so that it is almost impossible to determine the kind of wood used for the interior trim. Why should it not be possible to have interior trim of walnut, mahogany or any other cabinet wood that might be desired? But, if such trim was to be made of solid wood, it would be almost prohibitive in price, besides being almost unobtainable in any volume. It requires lumber of a high grade, clear one face or better, to make interior trim; in addition, a large amount of wood is wasted in the shaping almost any pattern. These two factors make the cost of interior trim in woods like walnut and mahogany very high. But, if this interior trim could be molded, using a waste-wood core and a veneer face of the desired wood, the price could be reduced to a figure comparable to that of solid gum or unselected birch trim. Also it would make possible the use of more than one kind of wood in the same house at little or no difference in cost.

This paper covers the process of making interior trim from veneer mill waste, using a sheet of veneer as the exterior face and a waste-wood core. Briefly, the process consists of reducing the larger particles of waste in a hammer mill, drying the waste to less than five percent moisture content (dry-weight basis), and then mixing the dry waste with a resin binder. A sheet of veneer is placed in the cavity of a metal die of the desired pattern, after which the cavity is filled with the waste resin mixture. The two parts of the die are placed in a hydraulic hot press where heat and pressure are applied for a sufficient length of time to cure the resin binder. The finished piece of trim is then removed from the press, trimmed, and packaged.

Waste Wood Preparation

The method of preparing the wood waste for use in the manufacture of interior trim is identical with that required for the manufacture of flat panels or core stock from waste wood. The drying of waste wood from a face-veneer operation presents a greater problem than when the waste is derived from air-dried or kiln-dried material, since the veneer waste frequently has a moisture content of as much as 100 percent. This waste must be reduced to a moisture content of less than five percent to prevent blistering when the resin is polymerized.

Interior trim can be made using any type of adhesive as a binder, but, in order to make the trim as water-resistant as possible, a phenolic resin is employed. Interior trim is occasionally subjected to moisture, necessitating the use of this type of resin. Shorter curing cycles are possible when urea resins are used.

Design of Interior Trim

The design of interior trim should satisfy several conditions: (1) It must be appealing to the eye, (2) must have the simplicity necessary to bring out the beauty of the wood, (3) must for this process be capable of being readily molded, (4) must be of a width and thickness which can be used in most types of construction, and (5) its design must be such that it is easily cared for by the housewife. Many patterns and many shapes were considered, but it was decided that a pattern with a curved contour, a symmetrical pattern, would best meet all of the conditions listed above.

If standard thicknesses of veneer were to be used as faces, the molding limitations of those faces had first to be determined. Unless the veneer had been previously treated, it was found almost impossible satisfactorily to mold a panel that had the face bent at right angles, without rupturing that face at some point along the edge. There was no definite radius of molding that was the minimum for all woods used for veneer. The following points have been found to be applicable to the molding of the faces:

(1) The face can be molded through a one-quarter inch radius without rupture.
(2) Some woods can be molded using smaller radii than others.
(3) The method by which the face has been cut affects the radius. Rotary-cut faces can be molded to sharper radii than sliced.
(4) If the thickness of the veneer is reduced in the same wood, the molding radius decreases.
(5) Compound curves or combinations of curves and planes can be molded with little difficulty, if the width of the molding is not less than two inches.

Narrow strips are impractical to mold, since the dies required are more complicated and difficult to fill with the waste wood and resin mixture. If a narrow strip is required, such as a base shoe, window stop, or door stop, it is more convenient to mold it as part of a wider piece and rip the deserved strip from the wider piece after the entire molding has been made. The base shoe and the baseboard are molded as one piece, since most homes and buildings require equal amounts of each. The wider the trim, the easier it is to mold, even though it may require more complicated dies.

Plinth blocks that have four exposed surfaces can be molded, if the veneer has been die-cut so that each edge will match or join when pressure is applied. This type of molding requires more complicated dies, since the face must be forced into place before the waste wood is placed in the die cavity. Plinth blocks are molded in pairs and then separated when the binder has cured.

It has not been necessary to use "balanced" construction, in the plywood meaning of the term, in the manufacture of molded interior trim. Since the back of the trim is never exposed in homes or buildings, it is not necessary to face this side. Instead, the shape of the back of the trim has been designed primarily to give uniform thickness to the trim, so that the cure of the resin is identical throughout. Two bearing surfaces are molded as part of the back, in order that the trim will fit into the construction of the building or home.

Die and Press Design

The quantity production of interior trim indicates that a multiple opening press is neces-

sary. Each opening must contain the maximum number of dies possible, in order to obtain this production. Dies eight feet in length have been found to be the most economical. When using this length of trim, the waste factor is reduced to a minimum.

The cost of dies is so great, approximately $2,000 per opening for a 36-inch press, that frequent design changes are not desirable. The dies must be machined to a very close tolerance. All dies of the same design must be identical, so that there will be complete interchangeability of the molded trim. The changing of dies requires an almost complete disassembly of the press; therefore, frequent die changes are not economical.

For ease of loading and unloading, the press should have the ends open. In order to keep the dies hot and the number required to a minimum, removable cauls are used. These are loaded and unloaded outside the press. This permits the shortest press cycle possible, thereby allowing maximum production from the press.

Limitations

There are several factors which limit the manufacture of interior trim from wood waste. If the trim is to be sold in large quantities, it must not be priced "out of the market." The production of interior trim from wood waste is not economically practical for a manufacturer, unless the following factors are present:

(1) There must be sufficient hardwood waste available to produce a large volume of interior trim—at least 15 tons per day. All indications are that the use of softwood waste is not practical.

(2) The supply of face veneer must be available at a reasonable price, preferably at the cost of manufacture. The lower the price of veneer, the cheaper will be the final cost. If a manufacturer has a sufficient quantity of waste wood available, but is required to buy veneer at current prices, he will find the manufacture of interior trim unprofitable.

(3) The design must be such that frequent die changes are not required.

(4) A multiple opening press, having the maximum number of dies, is required in order that large volume production may be obtainable.

Conclusions

The production of interior trim, having a veneer face and a waste-wood core, is an outlet for the wood waste developed in the manufacture of face veneer. The process is economically practical only for such a manufacturer. The design must be such that the largest possible volume can be produced and sold.

Discussion

Prof. E. George Stern (Virginia Polytechnic Institute): A relatively large amount of binder seems to be used for bonding the molded wood-waste particles together. In view of this amount, is it necessary or desirable to provide the contact face of the veneer with a glue line, or is the binder added to the waste sufficient to provide the required bond between veneer and waste? Does the amount of binder result in a sufficiently satisfactory flow of the material to allow extrusion without increasing the density of the material and, if so, would extrusion of the waste be practical and feasible? Information on the amount of binder used, molding pressure applied, and on the particle-size limitations for satisfactory molding would be of interest. Are data available on stability, that is, resistance to warping and cupping upon exposure to relative humidity, or does the relatively large amount of binder used prevent the finished product from warping?

Mr. Burkhart: We have found that we obtain satisfactory face bond 80 percent of the time without applying glue to the face, but we do not know when the 20 percent failures will occur. In order to keep the number of reject pieces to a minimum, the faces are coated with glue prior to being used. We have not been able to extrude this material satisfactorily. We have contacted several manufacturers of extrusion machinery and have found that there are two factors which almost prohibit the extrusion of this type of material. The size of the chips is too great, and the cure time of the binder is too long. It would require excessively long dies to get satisfactory set of the glue by ex-

trusion. To date we have had no excessive warping or cupping of the finished material. Some installations, which have been in as long as 18 months, have shown no dimensional changes. Samples which have been constantly soaked in excess of two years have shown very little delamination and have increased in thickness less than 5 percent.

Mr. Burdett Green (American Walnut Manufacturers Association): Mr. Burkhart's paper seems to have covered, in a logical and thorough way, the general manufacturing and merchandising problems involved in his company's new product—Trimwood. It seems to me, however, that:

1. His assumption that most home owners want interior woodwork of a darker finish, in contrast to their walls and in harmony with their furniture, is not necessarily sound, nor is it necessarily easy to decorate interestingly under such conditions.

2. The general price comparisons with solid trim seem premature, without the company having developed better cost figures, based not only on actual production experience, but also on the actual merchandising of this product, which it may be necessary to handle through both wholesale and retail channels before it reaches the ultimate consumer.

In the merchandising of a product somewhat similar to this, we found that, in spite of a tremendous consumer interest and an actual desire to buy the merchandise, distribution inertia prevented the consummation of many sales. In a territory where the big volume of business is done in painted pine trim, the dealer stocks that item only, and considerable difficulty is encountered in planning ahead for the purchase and delivery at the proper time of a small amount of some special product.

3. If the product is shipped pre-finished, there will be considerable difficulty in cleaning up the defects caused during installation. Even is unfinished, the veneer-covered trimwood would not give the carpenter much to work with at uneven joints resulitng from uneven walls, etc. He has more to work on when trim of either solid walnut or solid pine is used.

I heartily agree with the points Mr. Burkhart makes on the ease of maintenance, etc., of the new product.

Mr. Burkhart (Replying to various other questions from the floor): For most applications, where only a small amount of cutting will be done, ordinary hand tools can be used in working this product. The material is slightly abrasive, requiring the use of carbide tipped saws and knives in quantity production.

Regarding the possible use of low-grade veneers over the core for trim that is to be painted, I would call attention to the fact that the basic cost of the process is the same regardless of what species of wood is used as the external face. We are selling the natural beauty of the wood, rather than any type of trim that is to be painted white. If the home owner desires to paint this figured piece of wood, he can, but he has paid for the beauty of the wood. In addition, we have found that the trend is away from white woodwork and to the natural finishes.

As the paper states we are interested in curved surfaces for trim, plus the fact that trim must have the exposed edges covered by the face. It is impossible to accomplish these conditions when a 4 x 8 foot panel is made and then cut to size.

For most installations it is believed that urea resin binders will give as satisfactory results as the phenolic resins. However, due to the shortage of urea resin, and to give the maximum water resistance to the material, a phenolic resin was used. The use of urea resins would reduce the pressing cycle, thereby increasing the production.

A direct comparison of the urea and phenolic resins as binders has been made and the phenolic resins have proven to be the most satisfactory. In spite of all precaution, interior trim will be subjected to some moisture. We have found that, when the urea resin bonded trim has been subjected to moisture, it swells approximately 20 percent in thickness; also there is more tendency for the face to peel than when phenolic resins are used.

We feel that it is not feasible to compare a low-grade cheap hardwood with wood waste

from a cost standpoint in this project. We want to utilize our wood waste—not to produce more waste, as would occur if a low-grade cheap hardwood was used. It is far cheaper to use wood waste, since you have no machining operations; the cost of moulding a hardwood core would be excessive, and then you would still have to glue the face to the core, which would require formed dies of one sort or another.

We have found very little trouble with bleed through in preventing the use of a penetrating stain, except during periods of very high humidity and high temperature, such as were experienced in August, 1947.

FOREST PRODUCTS RESEARCH SOCIETY

Wood Pulping By the Asplund Defibrator

Uno Lowgren

President, American Defibrator Inc., New York, N. Y.

Wood chips are pulped in the ASPLUND Defibrator at elevated temperatures in a steam atmosphere corresponding to pressures of between 125 and 175 pounds per square inch. The wood chips are continuously introduced into a high temperature preheating chamber by means of a screw or a reciprocating plunger feed. Heating by saturated steam at temperatures ranging from 350 to 370° F. causes softening of the binding substances, the so-called "middle lamella" between the individual fibers. After passage through the preheating chamber, the heated chips are carried to grinding discs where the fibers are separated. After defibration the pulp is blown from the defibrating chamber through reciprocating or nozzle valves to a collector under atmospheric pressure. The pulp produced, the so-called "ASPLUND fiber," is quite free and consists mostly of undamaged fibers. The steaming and defibration process does not affect the chemical composition of the pulp to any greater extent unless chemical agents are present during the operation. Power consumption is low. Fiber produced is suitable for building boards, such as insulating and hardwood; also for roofing felts as rag substitute and as bulk fiber.

Introduction

THE ASPLUND Process, named after its inventor, Arne Asplund, is principally a mechanical separation of fibers carried out at elevated temperatures of from 350 to 370° F. The material to be pulped is heated by steam, at pressures of from 125 to 175 pounds per square inch, and becomes thoroughly softened. The softening of wood material mainly affects the binding substances between the individual fibers, the so-called "middle lamella". The softening effect of heating of wood has long been known and utilized in various ways in the pulping industry. One example is steaming of logs before they are converted into ground wood pulp in a grinder. Another example is the steaming of chips in a digester for various periods of time and, upon release of the steam and discharge from the digester, the subsequent pulping of the steamed chips at atmospheric pressure. The ASPLUND fiber separation process, contrary to these older methods, takes place while the wood is still subjected to the high steam pressure and elevated temperature. The softening of the middle lamella, that takes place at such elevated temperatures as 350 to 370° F., has the same effect as if this substance had actually been melted. The separation of the fibers at these elevated temperatures can, therefore, be made at a relatively low power expenditure and the fibers produced remain mostly undamaged. The separation of the fibers is ordinarily not full complete and some bundles of unseparated fibers are usually present to varying extents.

For the proper separation of the fibers it is very important to have the wood material—usually in the form of chips—as completely heated as possible before the chips reach the pulping or defibration zone. The wood chips are, therefore, taken through a heating chamber which is under steam pressure of from 125 to 175 pounds per square inch. The time required to heat ordinary wood chips completely to the temperatures of the surrounding steam is from 60 to 90 seconds and is determined by several factors. One is the thickness of the chip—the thicker the piece the longer the time required; a piece of wood 1/4 inch thick will require four times the heating time that is needed for a piece 1/8 inch thick. The moisture content also affects the heating time. It is obvious, therefore, that the chips should be of as uniform size as possible and of the same approximate moisture content, so that they will be uniformly treated during the pulping process.

Operation of the Asplund Defibrator

The ASPLUND Defibrator is illustrated in the flow diagram (Figure 1). The various steps of operation which, combined, constitute the Asplund Process are as follows:

1. Feeding of chips into the preheater
2. Steaming of chips
3. Defibration
4. Discharge of fibre

1. Feeding of Chips

The wood chips are usually supplied to a chip bin located above the feeding end of the machine. This bin ordinarily holds a supply of chips equivalent to from 8 to 16 hours of operation. The chips flow downward into a special hopper equipped with a vibrator, which makes the chips flow down in a steady unbroken stream.

The apparatus that feeds the chips into the preheater is either of the screw type—as shown in the flow deisgn—or of the reciprocating plunger type. The purpose of either of these designs is to compress the chips into a continuously moving plug of sufficient density to seal off the steam in the preheater. The screw feed consists of a conical screw of a compression ratio of about 2.4 to 1, which, incidentally, is approximately the ratio of volume of chips ordinarily packed and its corresponding volume in the original solid wood. The chips are moved forward and kept from revolving by means of splines in the throat surrounding the screw. The chips are delivered and packed into the so-called plug pipe. This pipe is slightly conical-shaped and smooth. Its length varies from 14 to 28 inches, depending upon the type of chips employed—whether fine or coarse and whether of deciduous or coniferous wood. The conical bore will also vary for one type of chips to another.

As most chips are prepared from green wood or wood waste, they will carry with them the natural content of wood moisture or sap. During the heavy compression in the screw feed throat, a substantial amount of free wood moisture will be squeezed out. This moisture is removed through holes drilled in the throat and through the water slots located in the flange of the throat.

2. Steaming of Chips

As the plug of chips emerges from the plug pipe opening in the preheater, the plug expands and falls apart almost instantly. As the preheater is under full steam pressure, ranging from 125 to 175 pounds psi., the heating of the chips starts immediately. As the steam gives up its heat, the condensate is precipitated upon the chips and form additional moisture. Saturated steam is preferred, as highly superheated steam can literally "dry out" the chips and cause burning of the fibers on the grinding discs.

The steaming action of wood is always accompanied by formation and release of acids, such as formic and acetic. The longer the heating, the greater the amount of acids released. It therefore follows that the chips in the preheater become aciduous and the amount of acid present at the elevated temperature employed is sufficient to accelerate hydrolysis of the hemicellulose in the wood. This hydrolysis primarily converts the pentosanes into water-soluble pentoses. This effect is more pronounced the longer the heating is carried out. The yield of the pulp produced is, therefore, in direct relation to the steaming time. The steaming time also affects the color of the chips, and gradually causing them to darken. This darkening is attributed to the partial transformation of the lignin chain.

Due to the presence of formic and acetic acids, the hydrogen-ion concentration in the wood moisture will vary from 4.5 to 5.5 percent, which requires that the material in the preheater be acid-resistant.

3. Defibration

The fiber separation or the defibration of the steam-heated chips is carried out by grinding discs. These consist of one stationary and one rotary disc, the latter also movable axially and is kept under heavy spring pressure.

The chips are carried to the center of the stationary disc by means of a screw conveyor located below the horizontal preheater. As the chips enter the space between the two discs, they fall downward but are immediately caught by the vanes of the grinding discs and thrown out to the periphery. The space between the discs is shaped like a wedge pointed towards the periphery, and the diminishing space between the discs and the rotary force gradually breaks up the chips into fiber bundles. As these fiber bundles reach the grinding zone the fiber separation is completed and the pulp passes through the discs, which at this point are only about .002 inch apart.

Power consumption required for the grinding discs is from 125 to 160 Kwh. per ton of bone dry pulp. The power expended upon the fiber during the separation process is almost

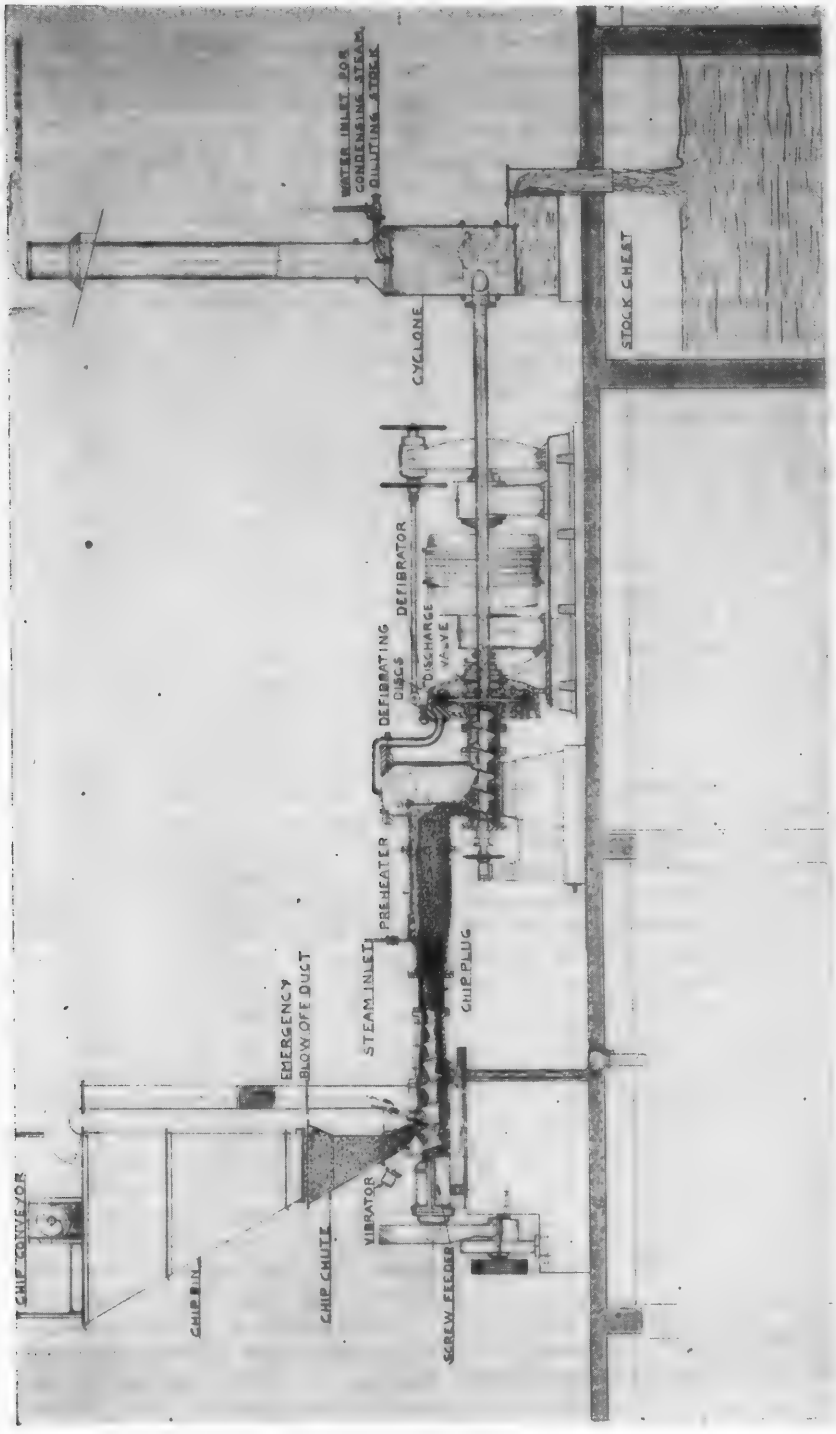

Fig. 1.—Flow diagram of Asplund defibrator.

entirely transformed into heat. This means that the released heat raises the temperature of the discs themselves as well as the fiber passing through the grinding zone. This temperature increase, in effect, means evaporation of some of the free water carried by the fiber—whether original wood moisture or steam condensate. It is, therefore, obvious that a minimum of moisture must be present during the separation process, to permit the absorption of the released heat. Otherwise the fiber would be overheated and gradually char or carbonize. Such carbonization of fiber occasionally takes place when the wood used is too dry, or if highly superheated steam is used; also if the spring pressure upon the rotating disc is kept too high. It is, therefore, a standard rule that the moisture content of the chips should not be below 30 percent, in order to prevent burning of the fiber or carbonization during the grinding operation. If chips of a moisture content below 30 percent are to be used, it is practical either to wet the chips before they are introduced into the Defibrator or to add extra water by pumping it into the horizontal preheater.

4. Discharge of Fiber

The ASPLUND pulp released from the defibrating zone is collected in the housing covering the grinding discs. This housing is also under full steam pressure. The pulp is released from this chamber to the open air through discharge valves. The valves usually employed are of the reciprocating type, consisting of two valves with a discharge chamber located between them. These valves open and close alternately, like a lock system. Another type of valve consists of a small orifice, the size of which can be regulated by a handwheel. The size of this orifice is regulated to permit all the fiber to be released while still keeping the quantity of steam released to a minimum. Due to the extremely high velocity of the expanding steam, this type of discharge valve requires careful design and the use of highly wear-resistent material.

The released pulp is usually collected in a cyclone, where the steam is condensed by a water shower and the pulp made into a stock suspension.

Properties of Asplund Pulp

The Asplund fiber as discharged from the Defibrator is a very free pulp and usually contains about 50 percent moisture. If dried in this form, it is quite resilient.

The color of the fiber is slightly darker than the color of the original wood. If the natural content of bark is mixed with the wood chips, the fiber will be considerably darker in color than that prepared from bark-free chips.

The yield of the Asplund fiber varies from 85 to 95 percent. The yield depends upon various factors, such as the steaming time and wood species. Ordinarily wood chips contain from three to five percent water solubles. The steaming process of 1½ minutes in the Defibrator will add another three to five percent to these water solubles. The losses occur as the pulp is brought into stock suspension. If the pulp, therefore, is dried immediately after its release from the Defibrator, the water solubles remain in the fiber and the yield is considerably higher than if the pulp is washed.

Under the microscope the Asplund fiber appears mostly unbroken and undamaged. Its chemical composition is almost identical with that of the original wood, although the hemicellulose content of the fiber is slightly less, due to the losses caused by the hydrolysis. Certain changes in the fiber structure seem, however, to have taken place during the steaming and defibrating process. These changes become apparent when the Asplund fiber is subjected to further chemical treatment. If Asplund fiber is subjected to sulphite cooking, the resultant pulp will not possess the strength and other properties contained in pulp which has been produced from the original wood. Alkaline cooking, however, gives better results, but even here, for instance, the strength of kraft pulp prepared from Asplund pulp in the conventional manner, does not come up to the strength of regular kraft pulp. Exactly what takes place in the fiber structure to cause this lessening of strength during the preheating and defibrating process, has not been established, but it is apparent that some definite changes occur.

Further processing of Asplund pulp and its various applications involve beating and refining, and some times screening. For insulating board, a high degree of refining is important

to develop the necessary binding properties. For hardwood, a slight refining is usually beneficial to board strength. This also applies to the use of the pulp in roofing and flooring felt manufacture.

The above description refers to the Asplund pulping process as it is carried out in most commercial installations for non-chemical pulping. Several modifications of the process have been developed to meet specific requirements as to capacity of the feeding apparatus, length of heating time in the preheater, size of the grinding elements, as well as the use of various chemically-reactive agents added to the wood. All these variations, however, regardless of their relative importance, do not constitute any basic change from the original Asplund process, but are, rather, modifications that are inherent in the process itself.

Chemical treatment of the raw material in the Asplund process was recognized in the early stages by Asplund himself. The principle of the Asplund process adapted for semi-chemical or chemical pulping includes the steps of soaking the chips with a chemical solution, removal of excess liquor, aging—i.e., allowing the chemical solution to penetrate the chips completely at atmospheric pressure—and the feeding of the chips so prepared into the Asplund Defibrator. The subsequent heating of the wood chips in the Defibrator is accompanied by a delignification the extent of which is determined by the amount and nature of chemicals employed, steaming temperature and length of heating. The pulps so produced are suitable for various paper-making purposes, such as corrugating board, chip board, and the like.

Discussion

Mr. S. L. Schwartz (U. S. Forest Products Laboratory): Mr. Lowgren, continuous pulping devices have always intrigued me. However, I have not been impressed that it is powerwise to use the Defibrator as a means of preparing insulation and hard board stocks. (I am basing my remarks on the data presented by you before the Associated Forest Products Technologists at Longview, Washington, December 11, 1946, which appeared in the *West Coast Lumberman,* issue of February 1947.) For example, if we were to prepare insulating board stocks by means of a groundwood mill, the energy input would approximate 35 horsepower days per ton, or 626 k. w. hours per ton. The use of the Defibrator for a similar stock would call for the following:

1500 lbs. steam @ 150 lbs. pressure	=	524 k.w. hr. per ton
Asplund refining	=	190 k.w. hr. per ton
Beater refining	=	200 k.w. hr. per ton
Total		914 k.w. hr. per ton

The total of 914 k. w. hr. per ton makes no allowance for yields of less than 100 percent.

In the production of hardboard, I estimate that under extreme cooking conditions (yields of 80 percent) 1100 lbs. of steam would be required for preparing one ton of steam-cooked stock. Assuming 15 hp. days per ton for refining in an attrition mill to secure a hardboard of 3000–4000 p. s. i. in flexural strength, the electrical energy equivalent is:

1100 lbs. of steam @ 150 lbs. pressure	=	458 k.w. hr. per ton
Refining—15 hp. days per ton	=	265 k.w. hr. per ton
Total		723 k.w. hr. per ton

The Asplund Defibrator would require 714 k. w. hr. per ton. This figure is based on the steam and electrical energy consumed in preparing Asplund fiber and without further refining. Though the Defibrator in this instance rates slightly better than the separate steaming and milling procedure I cite, I find it hard to believe that a good hardboard can be made from unprocessed Asplund fiber.

Mr. Lowgren, your comments on these points will be most welcome.

Mr. Lowgren: The comparison given on power and steam consumption is purely theoretical, inasmuch as the conversion of steam into electric power does not take the cost situation into consideration. If your argument were valid from a cost point of view, it would actually mean that 1500 lbs. of steam would be equivalent to 524 k. w. hr. Using an average steam cost of $0.40 per thousand pounds, the cost of 1500 lbs. of steam would be $0.60. This would mean an electric power cost of only $\frac{60}{524}$, or = 0.115 cent per k. w. hr. Such a power cost is not obtainable.

As you undoubtedly know, the present power cost varies from 0.5 to 0.9 cent per k. w. hr. for industrial usage. If we use an average figure of 0.7 cent per k. w. hr., and a steam cost figure of 40 cent per thousand lbs., the comparison in cost for Asplund fiber and groundwood pulp will come out as follows:

A. *Insulating Board*		
1. *Groundwood Pulp*		
626 k. w. hr. per ton at 0.7 cent per k. w. hr.	=	$4.39 per ton
2. *Asplund Pulp*		
1500 lbs. of steam at 40 cent per 1000 lbs.	=	$ .60 per ton
390 k. w. hr. per ton of fiber at 0.7 cent per k. w. hr.	=	2.73 per ton
Total		$3.33 per ton
B. *Hard Board*		
1. *Attrition Mill Fiber*		
Steam—1100 lbs. at 40 cent per 1000 lbs.	=	$ .44 per ton
Electric Power—265 k. w. hr. per ton at 0.7 cent per k. w. hr.	=	1.86 per ton
Total		$2.30 per ton
2. *Asplund Pulp*		
Steam—1500 lbs. per ton at 40 cents per ton	=	$ .60 per ton
Power—190 k. w. hr. at 0.7 cent per k. w. hr.	=	1.33 per ton
Total		$1.93 per ton

The above comparison shows that the manufacture of Asplund fiber is less expensive than either groundwood pulp or attrition mill fiber, which supports the experience of users of Asplund Defibrators.

Most hard board in Europe is prepared from 100 percent Asplund fiber, and most mills do not have secondary refining. The use of 100 percent Asplund fiber produces a hard board having a modulus of rupture of from 4500 to 6000 lbs. per sq. in. The average power consumption for hard board manufactured in Europe is 450 to 550 k. w. hr. per ton, including chipping and defibration, as well as all subsequent handling of stock into the finished product.

Mr. Lowgren (In reply to various questions from the floor): Maintenance costs depend upon how the local maintenance is kept. Grinding segments give 300 to 1000 hours service, depending upon raw material and kind of product manufactured. The average maintenance cost figures are from $.75 to $1.00 per ton.

It is correct that modulus of rupture in bending tests must be related to the density of the material tested. Ordinarily for hard board, it is understood that the modulus of rupture refers to material having a density of 1.0.

Uniform moisture of chips can be obtained in several ways. The chips may be wetted after they are discharged from the car, if delivered by rail, or on the conveyor into the chip bin. Ordinarily it takes from four to five hours for the water to penetrate completely into the chips.

The cost of Asplund pulp varies from one location to another, and depends upon the cost of electric power, steam, labor, and utilization of the equipment. For a steam cost of 40 cents per thousand pounds, a power cost of 0.7 cents per k. w. hr., and a labor rate of $1.00 per hour, the average overall conversion cost varies from $4.00 to $6.00 per ton.

FOREST PRODUCTS RESEARCH SOCIETY

Wood-Fiber Production with Revolving Disk Mills

Clinton K. Textor

The Bauer Bros. Co., Springfield, Ohio

The principles, design and operation of revolving disk mills is decribed. The science of fiberizing wood is undeveloped and the selection of equipment and procedures is dependent upon experience and specific experiment. Wood is frequently steamed or cooked before fiberizing; procedures and equipment for such pretreatment are described. The use of disk mills in the manufacture of wall board, saturating felt, container board and paper is outlined.

Introduction

IN THE course of the development of the pulp and paper industry, a great many machines or "engines" have been proposed and used for producing masses of fiber direct from wood. Similarly, many types of mills have been used for the further mechanical treatment of the pulp so produced, or to treat pulps manufactured by the chemical cooking of wood, in order to improve the sheet-making properties of the fiber and to develop strength and other desirable qualities. Of the many devices tried, only three have had sufficiently wide acceptance to be considered traditional equipment of the industry. These are the grindstone for producing "groundwood" or "mechanical pulp" by the direct grinding of logs or sticks of wood, and two rotating bar mills, the hollander beater and the jordan engine, used to "prepare", "beat", or "refine" pulps for the actual paper-making operations.

Revolving disk mills in various forms, as for example, the burr stone mill, have long been used for reducing wood to pulp, wood flour, and a variety of intermediate products, especially for paper and board, but they never achieved wide popularity. The more modern form of disk mill or refiner entered the paper industry about 25 years ago and is being used increasingly for a multiplicity of purposes, such as for the production of pulp for paper, fiber board, and wallboard from raw or pretreated wood chips, for the development of strength and other properties of pulp for paper making, and for the repulping of waste paper. These several uses seem to be unrelated but are all merely logical applications of the same fiberizing effect of disk-mill treatment.

Design and Operation of Disk Mills

The general design of modern disk mills is illustrated in the accompanying illustrations. Figure 1 illustrates a "single disk" mill. Chips or other fibrous materials are fed in at the center of the mill and fiberizing is effected as the materials pass outwardly between a revolving disk and a stationary plate; for purposes of construction, the stationary plate may comprise part of the case, or it may be held by a non-rotating disk.

In the "double disk" machine both disks revolve, but in opposite directions. In the machine shown in the illustration (Figure 2), the raw material is fed into the fiberizing zone of the mill through the spokes of one of the rotating disks. However, the feeding may be effected through a hollow shaft, and this type of construction can also be used in the above-described single-disk mill, which is equipped with one rotating and one stationary disk.

The clearance between the plates is adjustable. In the units illustrated in Figures 1 and 2, the micrometer dial mechanism permits the control of the distance between the disks by increments of 0.001 inch up to three inches; actual operations generally require settings in the range of 0.000 to 0.050 inch clearance.

Experience has shown that there are real differences in the performance of a single-disk machine, as compared with a mill in which both disks revolve. That there may be differences in performance can be anticipated by a consideration of the action of the two types of mills. A ball in contact with both plates of a single-disk unit will be set in motion by the revolving disk, will roll on the stationary plate, and will travel in a spiral path from the

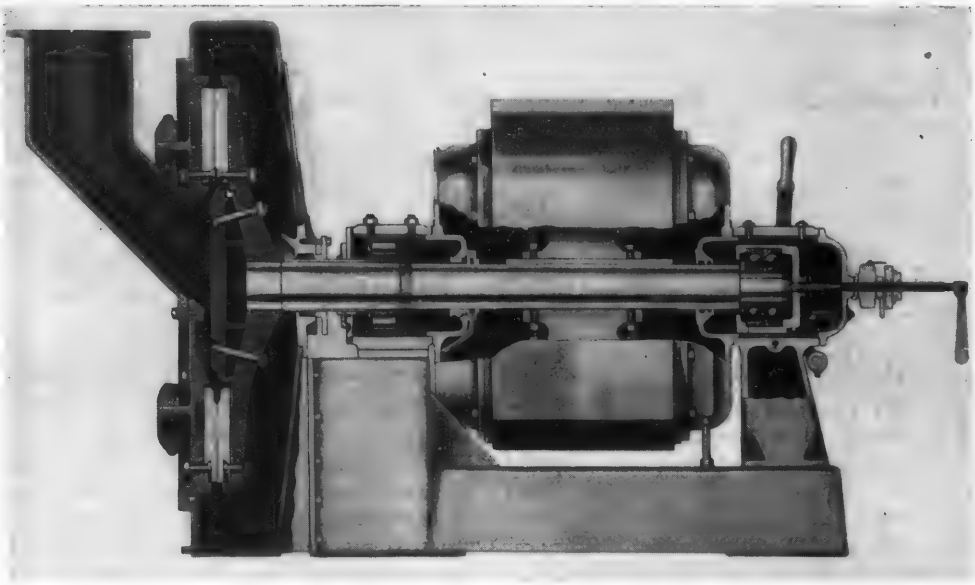

Fig. 1.—Single revolving disk mill.

center to the periphery. It will be subject to two centrifugal forces; the rapid rolling will tend to "explode" the ball, while the spiral travel will work to accelerate discharge of the ball from the machine.

On the other hand, a ball similarly placed between the plates of a double-revolving disk unit, will receive the same but opposite impetus from each plate; it will roll rapidly but will not travel outwardly as long as it is in

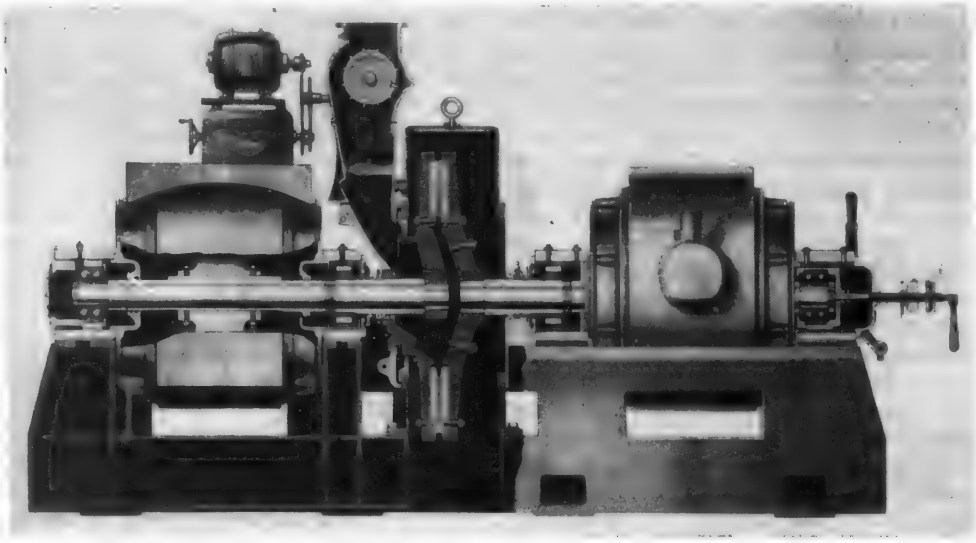

Fig. 2.—Double revolving disk mill with feed regulator for chips.

contact with both plates, except for other forces such as gravity, or the feeding of additional material. The only centrifugal force acting on a ball under such conditions is that tending to explode it.

While there are basic differences in the actions of the two types of disk mills, there are no scientific data for choosing the type better adapted for a specific job. Such a choice will have to depend upon experience in commercial operations, or upon tests made with full-size equipment. In both classes of disk mills, there is a considerable spread in the speed of rotation employed in individual unit. Both the productions by the machine and the quality of product is influenced by speed, which should be selected accordingly.

Actual designs of various makes of disk mills may depart radically from those illustrated in Figures 1 and 2. The shaft may be vertical and time of retention of material between the disks may be regulated by pressure devices. But all disk mills incorporate the simple basic ideas above pictured.

A special type of disk mill, in which fiberizing may be conducted at temperatures and pressures well above 212° F. and zero gage pressure, produces a unique type of fiber. However, the design and application of this type of fiberizer is properly the subject of another paper.

Usually the disks and the stationary "heads" are provided with renewable "plates," which do the actual refining job and which may be replaced when worn. These plates are designed for a variety of applications and involve an endless variation of groove and tooth pattern and dimension. Plates are sometimes available in the form of full circles, but generally they are produced in segments constituting one-third or one-sixth of a circle. A few representative patterns of the many which are in current use are illustrated in Figure 3.

As in the case of hollander beaters, jordan engines and other devices used to develop the potential properties of fiber, our basic knowledge of fiber and of the effect of mechanical treatment upon it is inadequate to explain or predict the performance of a disk machine upon a new raw material. Our knowledge of the theory in this field is too limited to serve as a base for the design of disk machines and their fiberizing plates. The information we have concerning the functioning of this type of machine is largely factual and descriptive and based either upon actual commercial experience or upon experimental investigation of means to achieve a specified fiber quality. And there is a considerable number of variables involved which have bearing upon the performance of the machine and upon the quality of product achieved. Unfortunately, these variables are of a nature which prohibits the use of miniature equipment for investigative purposes; this situation is similar to that which obtains in connection with investigations of beating and jordanning.

While the several variables are known and recognized, their individual influence and range

Fig. 3.—A few patterns of fiberizing plates.

is only sketchily understood and the correlation between them is still largely a matter of cut and try. Among the variables are such factors as (1) speed of rotation, (2) peripheral speed, (3) rate of feed, (4) relation of water to dry fiber (consistence), (5) pattern of fiberizing plates, (6) temperature of feed, (7) rate of power application, (8) distance between the plates, and (9) precision of construction.

No attempt will be made in this paper to provide an adequate explanation of what happens to materials, such as wood chips, in passing through a revolving disk machine. It is obvious that liquids passing through the unit will be violently agitated, and that solids large enough to have simultaneous contact with both plates will have a tendency to roll. Whatever the final explanation may be, experience has shown that disk machines are effective in producing masses of individual fibers (or small fiber bundles if desired) from fibrous aggregates, such as wood chips, old paper, straw and other materials. It has further been shown that such fiberizing is accomplished with substantially less shortening of ultimate fiber, as compared with a job performed with traditional equipment which involves the cutting action of "bars" or "knives" in beaters and jordans, or the abrading action of the "groundwood" pulping stones. Generally a single pass through a disk mill serves the purpose, but as many as four or five passes are used for specific objectives.

While there are inadequate data concerning the effects of the many variables previously indicated, to permit, without trial, a specification of speed, plate design, and power required to produce fiber of a definite quality from wood chips, there is however a mass of data from commercial operations and from laboratory investigations on which a fair idea of the fiberizing requirements can be predicated.

Fiberizing of Wood Chips

Wood is the raw material on which the following comments are based, although many of the findings apply equally well to other fibrous materials. And for the most part the comments apply to wood which is available in pieces large enough to produce chips of the general size and character of those conventionally used in the chemical pulp mills. Such chips can be taken as measuring one-half inch to one inch with the grain by one-eighth inch thick by one-half inch to one inch wide. (Brief mention of the use of bark, and smaller particles of wood, such as sawdust and shavings, will be made later in the paper). As in the case of chemical pulp, the best end products are made with uniform chips, which are best prepared from logs or cordwood sticks. But in many of the fiberized products produced from wood by means of revolving disk mills, the quality specifications are not too exacting and for most purposes sufficiently good chips can be made from many kinds of wood waste, such as slabs and edgings, logging waste, veneer cores and scrap, waste from box factories and furniture factories, and the extracted chips from the tanning and naval stores industries. Both the "hardwoods" from deciduous trees and the "softwoods" from the coniferous species are being fiberized effectively in commercial installations.

Wood in the form of chips and without any preliminary treatment can be fed to a disk mill to produce a variety of products, depending upon the moisture content of the wood, the species, and the method of milling. A considerable proportion of the wood flour made today is produced by fiberizing dry wood (10 percent moisture content) with disk mills. With a different type of plate, a mass of "match sticks" can be produced; this type of material is suited for further processing and at present has merit chiefly in that it produces a reasonably uniform size mass of match sticks from non-uniform wastes, such as hogged sawmill refuse.

Green or water-soaked chips fed to the disk mill with water will be discharged as a pulp somewhat similar in character to groundwood pulp; the power consumption is roughly equal to that required by the conventional grindstones in producing mechanical pulp of like quality. Considerable quantities of certain species are currently being fiberized, in green condition, for the manufacture of insulating board and hardboard.

There are no commercial installations of the use of disk mills in producing "groundwood" pulp for the manufacture of newsprint paper,

the nearest application being the use of revolving disk mills for the refining of groundwood screenings. However, this application may have merit, due to the fact that chips may be made from small or irregular sticks of wood which are unsuited to the conventional grinding procedures.

Cooking of Wood Before Fiberizing

Although a preliminary soaking, steaming, or cooking of the wood is an integral part of many of the applications to be described, all discussion of the traditional "full cooking" processes of the chemical pulping industry is omitted from this discussion. Such processes are completely described in the voluminous literature of that established industry.

These preliminary treatments of the wood will be considered in three groups, with (1) water at atmospheric temperatures and pressures, (2) water at elevated temperatures and pressures, and (3) water and chemicals at elevated temperatures and pressures.

The first group includes the steaming of the chips at atmospheric pressures, as well as the soaking or boiling of the wood in hot water. Such a treatment at atmospheric pressure has the effect of softening the chips somewhat and enables the disk mill to produce a pulp with fewer broken fibers and of a more pliable character, which "felts" together better into a stronger sheet of paper or board. In general this must be considered as a mild treatment, which will produce a modest increase in strength and quality, although often these modest increases are entirely adequate for the purpose. The degree of softening of the chip depends upon the species of wood involved, and upon the time and temperature of the soaking or boiling. There is generally a slight darkening of the wood incident to this treatment, which, in addition to improving the fiber quality, sometimes has the effect of lowering the power required in the fiberizing in other cases, the soaking has the result of toughening the chip and increasing the power usage.

The second group of pretreatments is practiced in two modifications, differing only in the proportion of water to dry chips involved. When only one to one and one-half pounds of water accompany each pound of oven-dry chips, the operation is generally referred to as "steaming". On the other hand, when there is free water present in addition to that absorbed by the wood itself, i.e., when each pound of dry chips is accompanied by three or more pounds of water, the operation is generally referred to as "water cooking". There is not a great deal of difference between the two types of operation; water cooking generally produces a somewhat better quality of fiber but involves a higher steam consumption, as compared with the steaming operation.

In actual applications, the conditions of cooking or steaming vary enormously, both as regards time and pressure involved and with reference to the quality of fiber produced. For producing various fiber qualities in commercial operations, this preliminary treatment will vary from a few minutes steaming at 300 psi. in one plant, to another in which the wood is steamed for 120 minutes at 30 psi. Very usable fiber is prepared from chips steamed for 15 minutes at about 100 psi.

The steaming or water cooking of wood chips has a profound effect on the quality of the wood, and long steaming can seriously reduce the yield and impair the strength of the fiber. Time and pressure should be chosen with reference to the fibrous product desired and to the species of wood involved. Different species have shown big differences in behavior when steamed; the bond in the wood from deciduous trees yields much more readily to this type of operation than does that in the wood from coniferous species.

The steaming operation induces a series of changes in composition and property of the woods. Some of these changes are permanent and some are reversible. The change in color, for example, is permanent, whereas the softening of the wood is in part reversible. Steaming softens the wood, but when the steamed wood becomes cool, it regains about one-half of its original hardness in the course of a few minutes. Thus wood that has been steamed can be fiberized at atmospheric pressure with much less power than was needed for the raw wood, and the fiberized product is much stronger and more pliable. The more pliable the fiber, the lower its resilience and the greater is its tendency to retain its compacted volume after

a wet pad or sheet of it has been subjected to pressure. Sometimes these properties are highly desirable, but at other times they are completely objectionable, and the pretreatment must be chosen with regard to the several qualities of fiber.

The plastic properties of wood are definitely influenced by a steaming treatment. When the proper time and temperature of steaming has been established for a particular species of wood, a fiberized product can be prepared which, after hot pressing, has much improved water resistance.

The third group of preliminary end treatments includes the many semi-chemical pulping processes. Strictly speaking, the scope of semi-chemical cooking comprises the entire field between "full chemical" cooking and no cooking at all. An almost endless number of semi-chemical processes results from various combinations of time of cooking, steam pressure, and the kind, quantity and concentration of chemicals used.

In actual practice, the semi-chemical processes are generally thought of as those in which a yield of 65 to 90 pounds of dry pulp is produced per 100 pounds of dry wood, and in which the chemical charge is from one-fifth to one-half that used in the "full cooking" operations. But there are a few plants in commercial operation whose wood treating operations must properly be called semi-chemical in which the charge is approximately one-tenth of that used for full cooking operations.

Probably the best known semi-chemical process is that frequently used in the investigations of the U. S. Forest Products Laboratory. In this modification the chemicals used comprise a mixture of about 80 percent sodium sulphite and 20 percent sodium carbonate. Many of the commercial semi-chemical operations use that particular procedure. But other semi-chemical mills are operating successfully and using caustic soda, sodium carbonate, sodium sulfide, and lime, either alone or in mixtures.

The selection of a semi-chemical cooking procedure should be made with respect to the species of wood involved, and the quality of fiber required for the particular end product. In actual commercial installations, the processes used have been thus selected. One may be little more than a water cook, modified by the addition of as little as ten percent of the chemicals ordinarily used for full cooking procedures. Another uses up to one-half of the normal cooking charge to produce a high yield pulp that can be bleached and used in the manufacture of fine papers.

All of these semi-chemically cooked chips require fiberizing of some sort before they can be used effectively in an end product, and so the semi-chemical pulp mills almost without exception employ revolving disk mills. Depending upon the degree of cooking and upon the quality of fiber required, the power required in fiberizing varies all the way from 30 horsepower per ton per day down to as little as five.

Equipment For Cooking Wood

There is no standard procedure and no standard equipment for conducting these preliminary treating processes. Most frequently seen in actual operations is a train of equipment generally outlined in Figure 4. This system comprises a globe rotary digester whose contents, after cooking, are dumped directly into a "hot chip" bin or on a conveyor which in turn delivers to the bin. Preferably, this bin is equipped with a turntable bottom or other means by which the chips may be discharged at a uniform rate. Then, by means of a suitable conveyor, the cooked chips are conducted to the feed regulators of one or more revolving disk fiberizing units, the surplus being returned to the hot chip bin. The chip feed regulators provide an accurate means of controlling the flow to the individual revolving disk mills. Usually a single pass through these mills is adequate to prepare a fiber for conversion into the desired end product. Frequently it is advisable to accomplish 90 to 95 percent of the fiberizing action in a single pass, screen off the oversized particles with suitable equipment, and return the rejects for a second pass through the disk mills. Many of the preliminary treatments generate substantial quantities of wood acids and in such cases it is advisable to use digesters lined with brick or acid resistant metal, and in general to use equipment which has a measure of corrosion resistance.

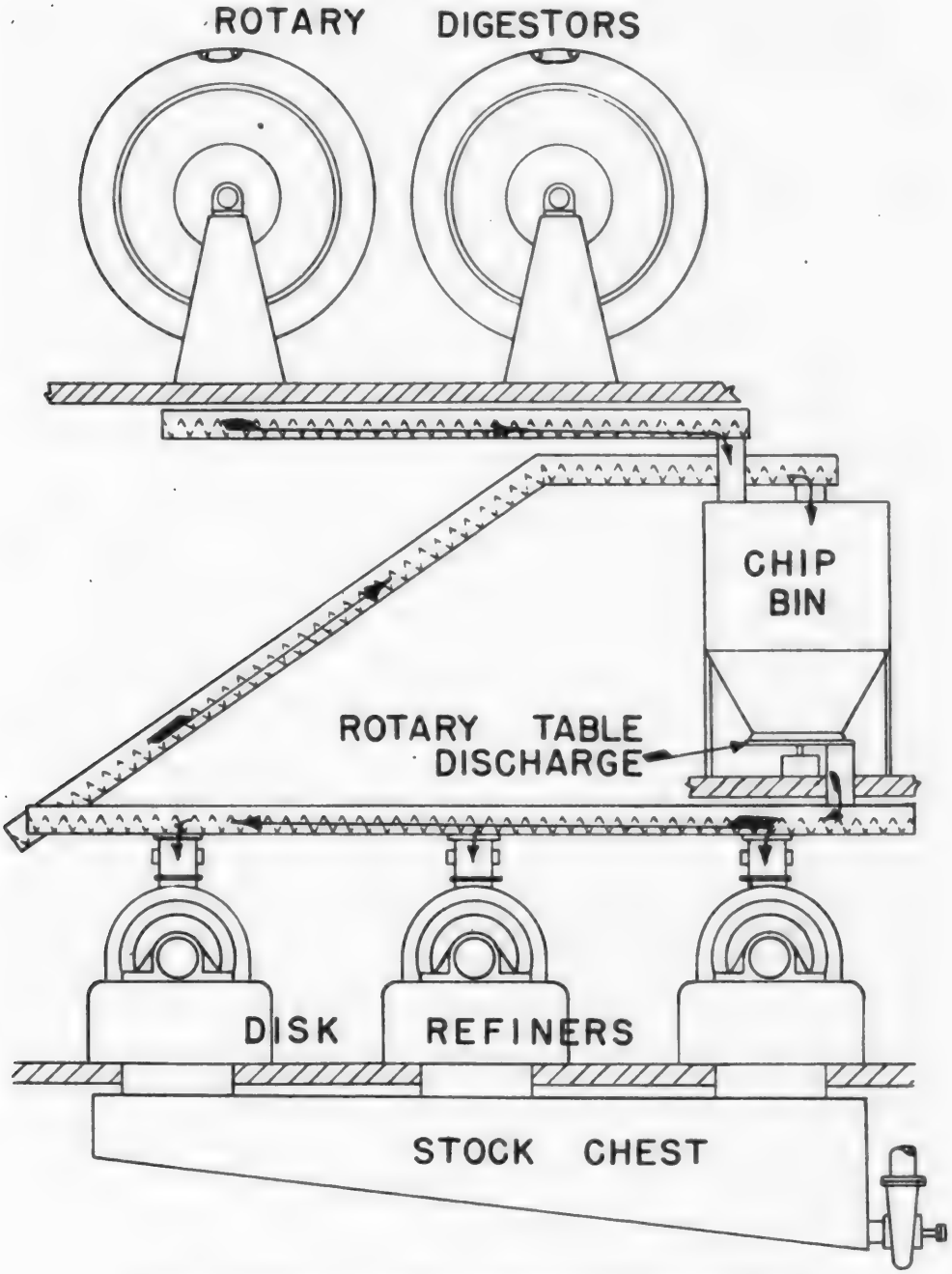

Fig. 4.—Flow sheet of a system for pretreating and fiberizing wood chips.

The system as shown is very flexible, simple, and relatively inexpensive in consideration of its capacity. Any number of digesters or refiners can be used in such a system. In some installations, a hot chip tank is provided for each digester, but a single chip storage bin of this type can serve up to five or six cookers, and would have the additional advantage of maintaining a higher temperature of the pretreated chips going to the fiberizing machine.

The size and number of digesters must be determined with relation to the requirements of tonnage, the time of cooking, and the quality of product desired. Spherical digesters are available in sizes ranging from 12 to 18 feet in diameter. A 16-foot diameter globe rotary will hold about eight cords of chips with the cooking cycle varying anywhere between one and one-half and eight hours, this means that each cooker can produce from 3 to 16 cooks in 24 hours of operation. The capacity of the system may be illustrated by two fairly extreme examples. Birch, a heavy hardwood, can be cooked to a yield of 85 percent at the rate of ten cycles per day; in such an operation, a 16-foot spherical digester would have a capacity of 125 tons of air-dry pulp per 24 hours. On the other hand, a light softwood such as balsam fir may be cooked to produce a different type of end product, at the rate of four cycles per day to 70 percent yield; in this case a 16-foot globe cooker would have a capacity of 22½ tons per 24 hours.

In place of the batch operation represented by the spherical cooker and the hot chip bin, any successful continuous digester or steaming apparatus which is able to discharge to atmospheric pressure can be located immediately ahead of the revolving disk mills. In addition to probable economic advantages of a continuous operation, it would doubtless discharge chips to the fiberizing machines at higher temperatures. In connection with steamed wood, this might help in that it would be possible to fiberize the chips before they had regained part of their original hardness.

An intermediate between the globe rotary system and the continuous cooker is a small automatically operated cooker, employing high steam pressures for very short periods. The entire cycle of a system of this type could be completed in seven to fifteen minutes.

A considerable range in capacity of the revolving disk mills is experienced in connection with the processing of various species of wood for a variety of end products. In most cases, the capacity of a double revolving disk mill equipped with two 150 HP motors is in the range of 15 to 30 tons of air-dry product per day. But in extreme cases capacity ranges of from 10 to 60 tons per day have been achieved.

In many installations in which fiberizing equipment is preceded by steaming or semi-chemical cooking, it is unnecessary to wash out the soluble matter of the pulp. In such plants, the washing operation is dispensed with entirely. Where washing is required, the operation varies in accordance with the degree of cleanliness required. It may be accomplished (1) by adding water to the digester and draining it off, (2) by spraying water on the chips while they are conveyed from the digester to the hot chip bin, (3) by washing in the hot chip tank, which has been especially provided with a perforated bottom, or (4), especially if a thorough wash is desired, it may be performed after fiberizing with the conventional equipment used in the pulp and paper industry.

Products Utilizing Fiberized Wood

A few of the commercial outlets for fiberized wood are described in the following paragraphs.

Wallboard (insulating).—Currently operating wallboard plants are successfully obtaining fiber for their product by fiberizing, with revolving disk mills, a variety of species of American and foreign woods, including white, jack, and yellow pine, Douglas-fir, balsam fir, red and black gum, willow, and aspen or poplar. In some of these installations, the disk mill comprises the sole means of fiber preparation; in others, the disk mills are used in conjunction with other means.

The pretreatment used in this industry varies with the species and a number of local factors. Spruce, balsam fir, aspen and some of the pines, in green or water-soaked condition, are being converted with disk refiners, without any pretreatment at all.

In the case of Douglas-fir, jack pine, and some of the yellow pines, the wood is given a steaming pretreatment or a mild semi-chemical cook prior to fiberizing.

Some of the hardwoods, such as gum and birch, in kild-dried condition, require a somewhat more drastic semi-chemical cook, resulting in a yield of approximately 80 pounds of dry pulp per 100 pounds of dry wood. Such fiber produces a superior quality of wallboard.

The power consumption in the above-mentioned applications varies from about 30 horsepower per ton per day down to about 12; this means that a disk refiner provided with 300 motor horsepower, will produce from 10 to 25 tons of air dry fiber per day.

Wallboard (hard pressed).—This is the product commonly known as hardboard. It is a highly specialized product and is prepared by a variety of processes. The board may be formed wet or dry, and may be sent to the heated platen press in either wet or dry form. Some of the processes rely completely on the wood to supply its own binder; in others, a binder is added, sometimes in the form of a synthetic plastic. The particular process employed determines the type of pretreatment and the fiberizing action required and both are subject to wide variations.

As previously noted, fiber from steamed wood produces a hardboard of superior water-resisting qualities, but on the other hand, excellent hardboard is being prepared from wood that has had no pretreatment at all. Both deciduous and coniferous woods are used in the manufacture of hardboard, and both are successfully handled in revolving disk mills.

Saturating Felt.—This product, chiefly used for roofing and for floor coverings, has traditionally been made from fibrous wastes of various kinds, especially old papers and rags. But the rag supply is unreliable and at times very expensive, so that in recent years fiberized wood has been employed to displace rags; in some cases a merchantable felt is currently being made from a furnish that contains no rags whatever.

The fiber strength requirement for this grade of product is not very exacting, although a certain minimum strength is required. Certain other qualities of fiber are of critical importance, especially its absorbency, which must be controlled within fairly narrow limits.

It has been found that excellent fiber for this purpose can be prepared from either hardwood or softwood by proper choice of preliminary treatment and fiberizing operations. Generally the wood is presteamed or given a very mild alkali cook, then fiberized at atmospheric pressure, using from 10 to 20 horsepower per ton per day in this operation. Without any other treatment, such fiber is ready to be mixed with fiberized waste paper and converted into felt.

Container Board.—Revolving disk mills have been used for aout 20 years in the production of this grade of board, and in recent years this type of equipment has been increasingly used for the purpose. Most of the grades of board used for manufacturing fiber containers require more fiber-felting strength than is needed for wallboard or saturating felt, but for certain of these grades, notably corrugating board, the strength requirement is well within the range of what can be achieved by means of a combination of semi-chemical cooking and and disk fiberizing. Wood from deciduous trees is used chiefly at present, and much of the current production of this type of material is predicated upon extracted chestnut chips and other waste wood.

Semi-chemical cooking for container board is frequently conducted with eight to ten percent of soda ash, sodium sulfite, or mixtures of the two, giving a yield of 80 to 85 percent. The cooked chips are then fiberized, using from 10 to 25 horsepower per ton per day for the job. The fiber so produced is ready for the paper machine, but is sometimes given an additional "preparation" treatment in the beater or the jordan, especially if cutting or shortening of the fiber is desired.

Fine Paper.—While experimental research work and some large scale semi-commercial tests have given uniformly high promise, there are at present no commercial installations producing fine papers from semi-chemical pulps. The data of the U. S. Forest Products Laboratory and of other sources indicate that a semi-chemical cook employing about 15 pounds of a mixture of sodium sulfite and sodium carbonate per 100 pounds of dry chips, will produce a pulp with a yield of about 70 percent

of the weight of the original wood, and that about 15 horsepower days per ton are required for fiberizing the cooked chips. The resulting fiber may be bleached to a satisfactory brightness with the use of about 15 pounds of chlorine per 100 pounds of pulp.

Because of the nature of the end product in this case, the entire cooking and fiberizing operation will have to be conducted with more care than is necessary for the previously named products. The condition and type of wood will have to be selected, and the chips required should be of a uniformity comparable to that used in the chemical pulping operations.

Fiberizing of Miscellaneous Wood Wastes

In addition to fiberizing chips, disk mills may also be used in a limited way in the production of fiber from certain other byproducts of the wood-using industries.

Shavings.—The waste from a planing mill operating on coniferous species offers an excellent source of fiber for certain purposes. After fiberizing, it is being used successfully as a partial furnish for insulating board and, along with waste paper, may be used for the manufacture of saturating felt. However, the pulps prepared from shavings are inferior in strength to those obtained from conventional chips of the same species. The general comments concerning the preliminary treatment for chips will apply similarly in the processing of shavings.

Sawdust.—The sawdust produced in ordinary sawmilling operations constitutes a poor source of fiber. A considerable proportion of the fibers has been cut in the normal operation and many more of them have been injured. The pulp produced from sawdust is consequently of inferior quality and has value chiefly as a filler or partial furnish, when the remainder of the furnish has surplus fiber strength.

However, dry sawdust is an excellent raw material for the manufacture of wood flour.

Bark.—Most types of bark contain so little ordinary fiber that they cannot properly be considered as a source of fiber, although substantial tonnages of bark are being processed along with wood fiber. In many commercial installations which involve the fiberizing of chips, with or without preliminary treatment, the bark which normally accompanies the log or slab is processed along with the wood. However, in the main, this practice is followed primarily to avoid the expense of bark removal and the bark is generally considered as, at best, a dead weight of inert material.

When processed through a revolving disk mill alone, bark is reduced, with very little power consumption, to a slimy mass, which drains very slowly and dries to a crinkly sheet, which is very brittle and apparently very weak. However certain types of bark, such as spruce, balsam and jack pine, have some constructive merits of their own for certain specific end products.

When bark is fiberized alone and then added to fiberized woods, as much as 25 percent bark can be included in the furnish of a wallboard machine without impairing the quality of the final product. Similarly, 10 to 15 percent of bark included with the wood used in a mild alkaline semi-chemical cook may be fiberized into a pulp for the manufacture of .009-inch thick board to be used for corrugating purposes. The corrugated product so produced is probably superior, rather than inferior, to a similar product made entirely from bark-free wood.

Discussion

Mr. S. L. Schwartz (U. S. Forest Products Laboratory): There is a tremendous interest throughout the country in the utilization of wood wastes, especially for conversion to insulating-board, hardboard, saturating felts, and container board. Mr. Textor's paper dwells on that subject and is as complete a survey of the tasks involved as any I have read.

Mr. Textor (replying to direct questions from the floor): Maintenance costs comprise chiefly the replacement of the fiberizing plates or segments. These costs vary over a considerable range, dependent chiefly on whether the material refined contains corrosive or abrasive ingredients. Plate life as low as five days and as high as one year has been experienced. A maintenance cost of 50 cents per ton is considered very high, and costs as low as ten cents per ton are on record.

Conventional sawdust from the average sawmill is good material for the manufacture of

wood flour but, except as filler, has little merit in the production of synthetic fibrous sheets. The so called "wood room sawdust" from a pulp mill is generally comprised of a considerable proportion of small chips and may be used in the production of certain types of paper and board. This question should be answered by a specific test upon the raw materials in question with reference to the end product desired.

The optimum consistency of stock fed to the refiner varies over a range of from 3 to 50 percent dry substance depending upon the objectives in refining. The most common range of consistency is between 6 and 10 percent.

A considerable number of pulp mills have for a long time been refining their knotter screen rejects into a pulp which they use for the manufacture of container board, mill wrapper, and like products. Refined knots in general are not attractive raw materials for subsequent bleaching. Insofar as the knotter rejects are really knot material, they comprise inferior fiber and are accompanied by considerable dirt.

FOREST PRODUCTS RESEARCH SOCIETY

Effect of Some Manufacturing Variables on the Properties of Fiberboard Prepared From Milled Douglas-Fir

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In the conversion of wood into fiberboard sheet materials, there are many interrelated processing variables that have a signficant effect upon the quality of the final product.

This paper presents the results of tests conducted at the U. S. Forest Products Laboratory, employing three similar pulps prepared by wet grinding raw Douglas-fir. The tests included conditions affecting drainage rates, solids content of wet-pressed pulp mat, specific gravity of dried mat, and the relationship of fiberboard strength to both specific gravity and power consumption in fiber processing.

Numerous curves are presented and many of the relationships follow well-defined mathematical laws. These data, although not specifically applicable to any fiberboard process, may be of considerable use in reducing the amount of experimental work needed to evaluate techniques of pulp processing and fiberboard manufacture.

It was beyond the scope of this work to attempt a correlation of these data with operating characteristics of a production-size installation.

Introduction

IN THE conversion of wood into fiberboards, there are numerous manufacturing variables, other than those involved in the processes of preparation of the base pulp stock, that are known to have a significant effect upon the qualities of the final product. The effect of some of these variables on several closely related pulps was investigated at the U. S. Forest Products Laboratory, so that information could be made available for general use in the development of fiberboard materials from wood.

All fiberboard products discussed in this report were prepared in laboratory-size equipment. Although some of these data may be applicable to large-scale operation, no correlation with production-size equipment was attempted in this work. The relations developed, however, are useful in that they do contribute to a clearer understanding of the relative significance of several process operations commonly employed in the production of fiberboard materials. Although these data are based on a comparatively limited number of tests, the results may serve as a guide or basis of comparison for other research in this field. They may also be of aid in establishing the optimum interrelationship of processing conditions needed to produce a material conforming to certain specifications.

Literature

Although considerable information on the process variables operative in the forming and drying of wallboards made from wood pulps has no doubt been developed in the laboratories of manufactures, little specific and comprehensive data have been published or disseminated.

A study of the variables involved when cornstalks were used was made by Sweeney and Arnold.[2] Another study involving the properties of over 200 materials, many of which were

[1] Maintained at Madison 5, Wisconsin, in cooperation with the University of Wisconsin.

[2] Sweeney, O. R., and Arnold, L. K.: Studies on the manufacture of insulating boards. Iowa Engineering Experiment Station, Bull. 136, 1937.

fibers of various sources, was made by C. D. Willson. His study, however, was more general than this report and did not relate to any particular forming process.

A closely related study, using both agricultural plant crop wastes and sawmill wood wastes for wallboards and insulating boards, was made by C. G. Weber.[8] The prime emphasis was on the fiber preparation, but some note was taken of process variables in forming the boards.

Scope

This report presents data pertinent to the manufacture of fiberboards from several pulps that were prepared at the Laboratory by wet grinding raw Douglas-fir chips in an attrition mill. The investigation included the following relationhsips, as determined experimentally:

1. Pulp consistency and drainage time.
2. Pulp temperature and drainage time.
3. Mixed pulp composition and drainage time.
4. Dewatering pressure and specific gravity of a subsequently oven-dried fiberboard.
5. Dewatering pressure and solids content of pressed fiber mat prior to drying.
6. Dewatering pressure and specific gravity of fiberboard subsequently dried at several pressures.
7. Typical time-temperature curves for fiberboards press-dried at several pressures.
8. Press-platen temperature and drying time required at several pressures.
9. Sheet weight of fiberboard and drying time required at several pressures.
10. Degree of fiber refinement and specific gravity of fiberboards dried at several pressures.
11. Drying time required for fiberboards of several sheet weights and various densities.
12. Specific gravity and modulus of rupture at one moisture content.
13. Power consumption per unit weight of dry fiber produced and strength of fiberboards derived from similarly prepared pulps.
14. Comparative relationship of drainage time and strength of three similar pulps to power consumed in the preparation of the pulp.

Of the foregoing relationships, many follow well-defined mathematical patterns, *i.e.*, they can be represented as straight-line plots on semi-log or log-log coordinates.

Experimental Procedure

Preparation of Pulp

In the preparation of the pulp, raw, bark-free chips of second-growth Douglas-fir were used. The chips were cut from green logs and were about 0.75 inch long in the fiber direction by 1.0 inch wide by 0.125 inch thick. Three lots of chips were milled in a 36-inch attrition mill of the double-disk type, at plate clearances of 0.010, 0.005, and 0.0025 inch, respectively. The water feed to the mill was at 15° C., and the feed rate of the chips was adjusted to develop a high-power loading on the machine. The oven-dry solids content of the discharged pulp was in the range of 8 to 10 percent.

During the course of the grinding operation, the total power consumption for each batch of chips was recorded. The actual power delivered to the grinding plates, however, is dependent on the motor efficiency, which, in turn, is related to the degree of loading. For this particular work an over-all factor of 0.85 was used as the ratio of actual power input into the wood to that measured by the power meter.

In order to simplify stock preparation and minimize possible complications in the interpretation of factors affecting board qualities, no water repellants or other chemical agents were used in preparation of these fiberboards.

Drainage Test Procedure

In the study of drainage-time relationships, a filtration test unit 9.5 inches in diameter, having an 40-mesh bronze wire screen as the filter medium was used. The pulp chest, which was readily removed from the base filter unit proper, was a cylindrical steel shell, 18 inches in height. A diagrammatic sketch of this unit and the related vacuum and collector accessories is shown in Figure 1. This unit was standardized by adjusting the regulating valve so that 12.71 liters of water at a temperature of 15° C.

[8] Weber, C. G.: Fiber building boards. Ind. Eng. Chem. 27, No. 8, 896, Aug. 1935.

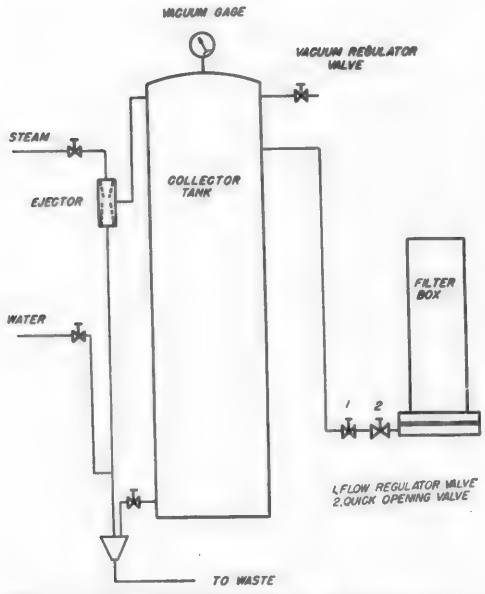

Fig. 1.—Diagrammatic sketch of apparatus used in preparation of experimental fiberboards.

were removed in 30 ± 0.5 seconds, when the vacuum in the adjacent collector tank was maintained at 15 inches of mercury.

Tests were performed in which consistency of the pulp stock was made the major variable, by holding the dry-sheet weight of pulp constant while the total water volume was varied. The drainage end point was arbitrarily defined as the point at which reflective water surfaces disappeared from the top area of the formed mat. Repeated trials with the same charge of pulp stock indicated a reproducibility on the order of ±2 percent.

Experiments, in which an attempt was made to determine the magnitude of segregation effect during formation of the wet mat, were conducted by diluting a well-dispersed pulp slurry to approximately 0.75 percent consistency. After agitation in the forming box, the suspension was allowed to settle freely for five minutes before the vacuum was applied to form the mat. During the settling period, no water removal was permitted and the initial drainage with vacuum was at a slow rate, so as to disturb the mat formation as little as possible.

In order to minimize the effect of a screen-dried surface insofar as possible, an 80-mesh bronze wire screen was used in the wet pressing and drying of these mats.

The study of the influence of temperature on drainage time was conducted by placing a well-dispersed pulp slurry in the test unit, then injecting steam directly into this suspension until the desired temperature was reached. The final adjustment of volume to exact consistency was done by adding water of the same temperature as that of the heated pulp suspension. The pulp slurry was then mixed and the vacuum immediately applied to form the mat.

An alternate method of operation of the drainage test unit was also briefly used in the temperature studies. The alternate system (Figure 2) consisted of a short barometric leg attached directly to the test unit and discharging into a constant-level overflow trap. The

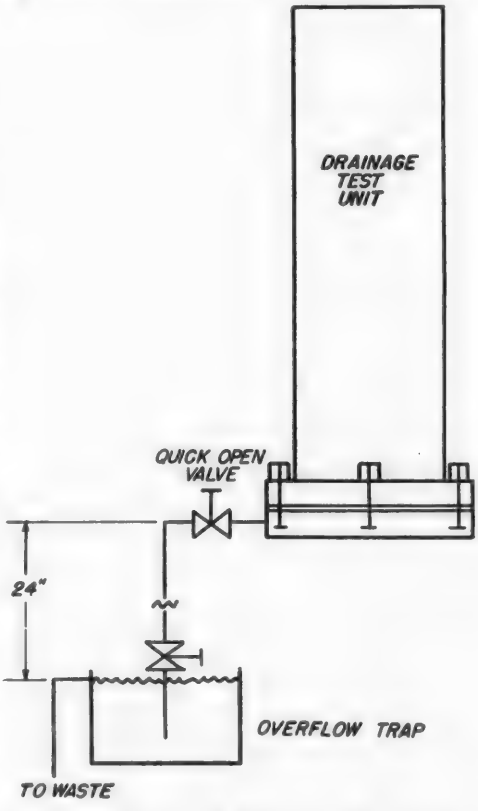

Fig. 2.—Diagrammatic sketch of modified apparatus used in preparation of experimental fiberboards, showing barometric leg attachment (between quick-opening valve and overflow trap) on the filtration test unit.

restriction was again adjusted, so as to give a 30-second drainage time for 12.71 liters of 15° C. water. The simplicity of this arrangement is rather attractive and it does obviate the flashing effect of the vacuum set-up.

Fiber Mats for Strength Tests and Press-drying Experiments

In the production of mats for strength tests and press-drying experiments, the circular filter unit was replaced with a 10-inch square forming box. The procedure used in preparation of these fiber mats was as follows: A thoroughly dispersed pulp suspension was charged into the forming box; the water volume was adjusted to give a consistency of approximately 1.50 percent, and, after brief agitation in the box to insure even pulp distribution, the mat was formed. A portion of the free water was removed mechanically from the formed mat by pressing it in a hydraulic press. The mat was first placed on a 16-mesh screen; stainless steel cauls were then put on each side, and this bundle, in turn, was placed on an 11-inch square plywood plate and then centered in a shallow steel tray which served to collect and drain the water squeezed from the mat during pressing. (This process is referred to as "wet-pressing" in this report.) The plywood plate supported the mat above the water level in the tray, so as to prevent standing water in the tray from being absorbed by the mat upon the release of pressure. The press was equipped with a manually operated valve in the hydraulic system, which permitted convenient control of the rate of ram travel and pressure development upon the compressed mat. The rate of compression is an essential factor in applying pressure to a wet fiber mat. Excessive speed causes rupturing, as the water cannot escape rapidly enough through the mat and screen, whereas extremely slow speed, although not harmful, is time consuming.

Those mats that were wet-pressed at normal temperatures were gradually compressed until the desired final pressure was attained, and this pressure was then held constant for approximately 60 seconds; the standing water along the edge of mat was blown off with a gentle air stream and pressure then released. The pressed mat was weighed to the nearest gram immediately after pressing.

In the series of mats pressed at elevated temperatures, the platen temperature was adjusted by mixing cold water and steam in the service lines to the press platens to correspond as closely as possible to the desired temperature. The mats were then prepared, using a heated pulp stock at a temperature slightly higher than that of the platen in order to compensate for heat losses during forming and transfer to the press. Just prior to placing the hot, wet mat in the press, a fine wire thermocouple was inserted at midthickness and thrust into the mat for a distance of about 1.5 inches. The temperature recorded was that indicated by the thermocouple immediately before the release of terminal pressure.

Mats that were oven-dried were placed in an electrically heated oven with forced-air circulation for a period of approximately 16 hours at 105° C. Press-dried mats had a screen placed on the lower surface and were then put between 0.125-inch stainless steel plates and dried in contact with the steam-heated platen of the press under constant pressure. The end point of the press-drying cycle was taken as the point at which no moisture was condensed on the surface of a cold, shiny metal spatula blade held momentarily near the edge of the hot mat.

To obtain the time-temperature data at the center of mats dried under several pressures, two mats of equal dry solids content were formed, and prior to wet-pressing a fine wire thermocouple laid between them. The combined wet-pressed mat with embedded thermocouple was then dried in the usual fashion, and periodic temperature measurements were made during drying.

The fiberboard specimens used in strength tests were made in duplicate and from each specimen four 1.50 inch wide by 9.50 inch long test pieces were cut. These test pieces were then conditioned for two weks at 70° F. and 65 percent relative humidity. All test sections were broken in static bending with the screen side of the piece opposite the surface in contact with the center loading head. The rate of head movement of the testing machine was four inches per minute in all cases. The specific gravity of test sections was based on the volume at test and weight when oven dry.

Discussion and Presentation of Results

Factors Affecting Drainage Time

The relationship of pulp consistency to drainage time is shown in Figure 3. This correlation is well established for a large variety of pulps, and these data simply confirm this basic relationship for a rather broad range of board stock pulps. Perhaps the most significant factor illustrated here is that an increase in

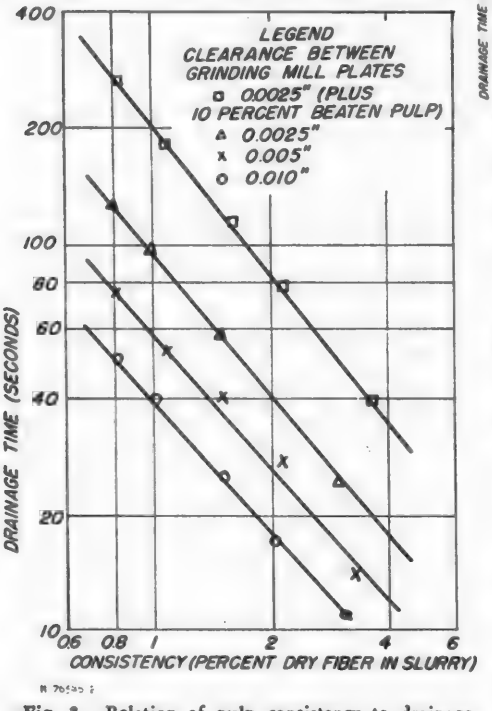

Fig. 3.—Relation of pulp consistency to drainage time for several board stock pulps. All tests were conducted at approximately 17° C.

pulp consistency produces more than a directly proportional decrease in drainage time.

The temperature-drainage relationships presented in Figure 4 and 5 indicated that, under certain circumstances of limited capacity in the vacuum system, the use of elevated stock temperatures may not result in reduced drainage time. This behavior was not what would normally be expected; that is, viscosity decreases with an increase in temperature and, therefore, the higher the temperature the shorter the drainage time. The cause for increased drainage times above 70° C. was believed to be the

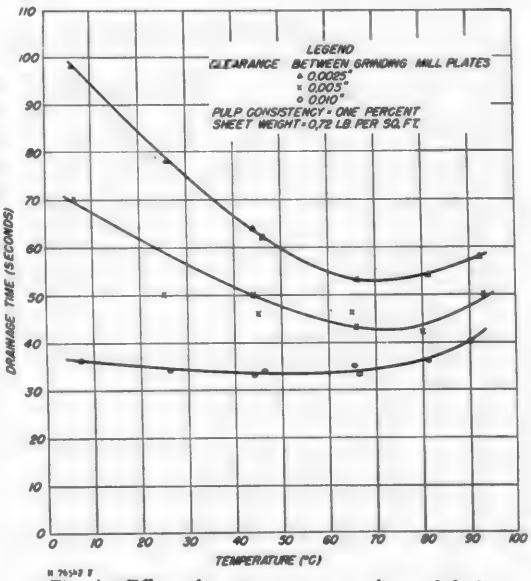

Fig. 4.—Effect of temperature upon observed drainage time of several pulps when water was removed by a vacuum system of limited capacity.

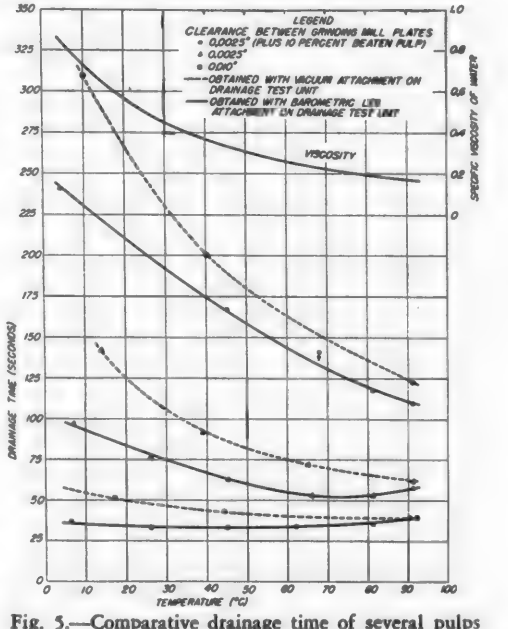
LEGEND
CLEARANCE BETWEEN GRINDING MILL PLATES
○ 0.0025" (PLUS 10 PERCENT BEATEN PULP)
△ 0.0025"
○ 0.010"
OBTAINED WITH VACUUM ATTACHMENT ON DRAINAGE TEST UNIT
OBTAINED WITH BAROMETRIC LEG ATTACHMENT ON DRAINAGE TEST UNIT
VISCOSITY
DRAINAGE TIME (SECONDS)
SPECIFIC VISCOSITY OF WATER
TEMPERATURE (°C)

Fig. 5.—Comparative drainage time of several pulps when tested by two different test methods.

Note: The solid and broken line symbols in the legend should be interchanged.

result of flashing of hot-water filtrate into the collector tank, with the consequent evolution

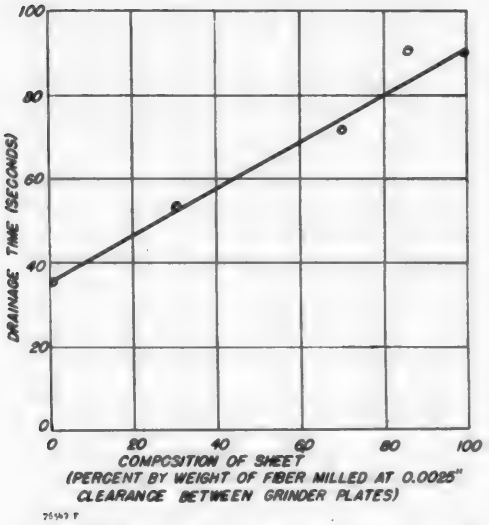
DRAINAGE TIME (SECONDS)
COMPOSITION OF SHEET
(PERCENT BY WEIGHT OF FIBER MILLED AT 0.0025"
CLEARANCE BETWEEN GRINDER PLATES)

Fig. 6.—Relation of mixed mat composition to drainage time. Fractions consisted of 0.010- and 0.0025-inch milled fiber.

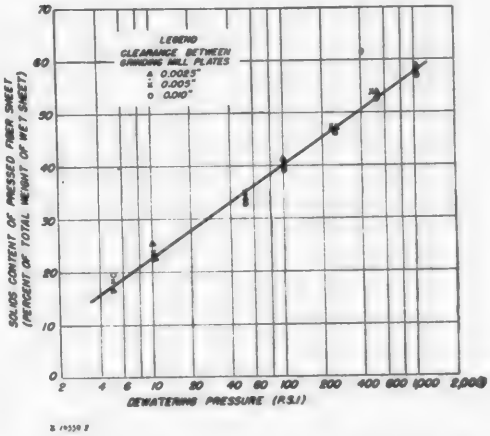

Fig. 7.—Relation of dewatering pressure to solids content of pressed, wet fiber mats prepared from similar pulps.

of steam in excess of the capacity of the exhaust system. This reduced the vacuum in the collector tank to such an extent that an appreciable increase in drainage time resulted. With an extremely slow-draining pulp, however, the rate of hot-water removal was slow enough so that the flash steam did not exceed the capacity of the exhaust system. Hence, in this instance, the pulp drainage characteristics were more comparable to the variations in the specific viscosity of water. Furthermore, the

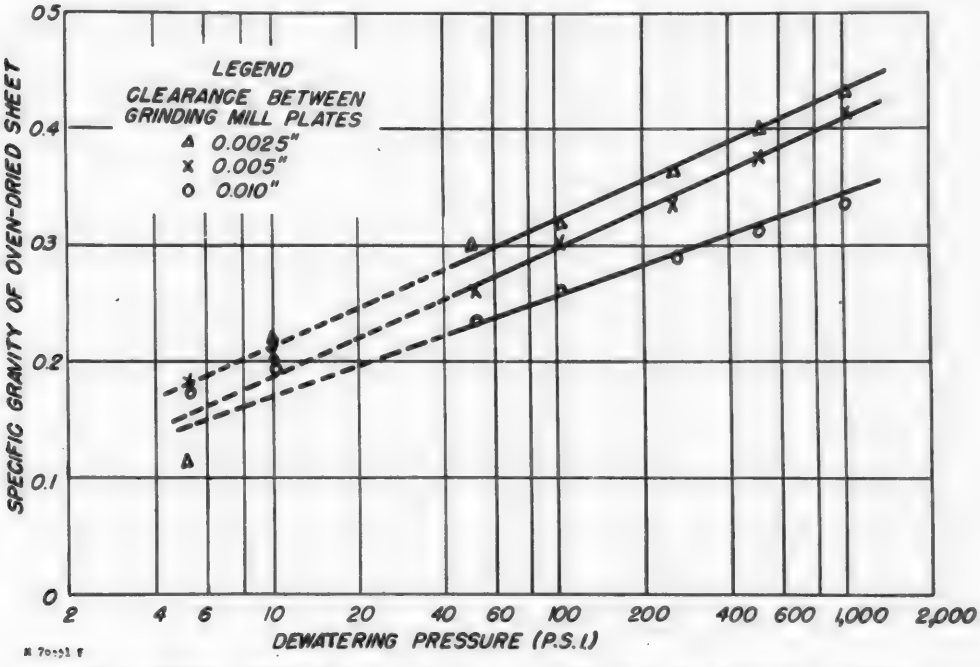

Fig. 8.—Effect of dewatering pressure upon the specific gravity of subsequently ovendried fiberboards obtained from three similar pulps.

order of magnitude of drainage time reduction by this means is clearly of secondary significance, as compared to the effect of relatively minor increases in pulp consistency.

The relation of mixed pulp composition to drainage time is given in Figure 6. These data are only approximate, but they indicate that similar pulps of not too widely differing drainage times will, when mixed, give a drainage time directly in proportion to the composition of the mixture.

Effect of Variations in Dewatering Pressures

A logarithmic relationship exists between the dewatering pressure and the solids content of the pressed mat (Figure 7). Probably of equal significance is the fact that, at a given pressure, similar pulps of varying degrees of refinement attain the same solids content. The rate at which pressure can be applied to different pulps, however, will vary, in general, in times vary. Hence, although the equilibrium solids content is virtually independent of fiber refinement, the rate of reaching the equilibrium the same manner as their respective drainage is closely related to the state of refinement.

Figure 8 shows the effect of dewatering pressure and pulp refinement upon specific gravity of oven-dried fiberboards. Here again the logarithmic relationship is marked, and it is also significant that an increasing degree of fiber subdivision results in an appreciable increase in density for a given dewatering pressure. It may be observed that there is an apparent departure, in the extreme low-pressure range, of the observed points from the curves shown. The reason for this is that the total pressing force was so small at 5 to 10 psi. that it was difficult to measure and reproduce these low pressures with the same order of precision that can be readily attained in the higher press-

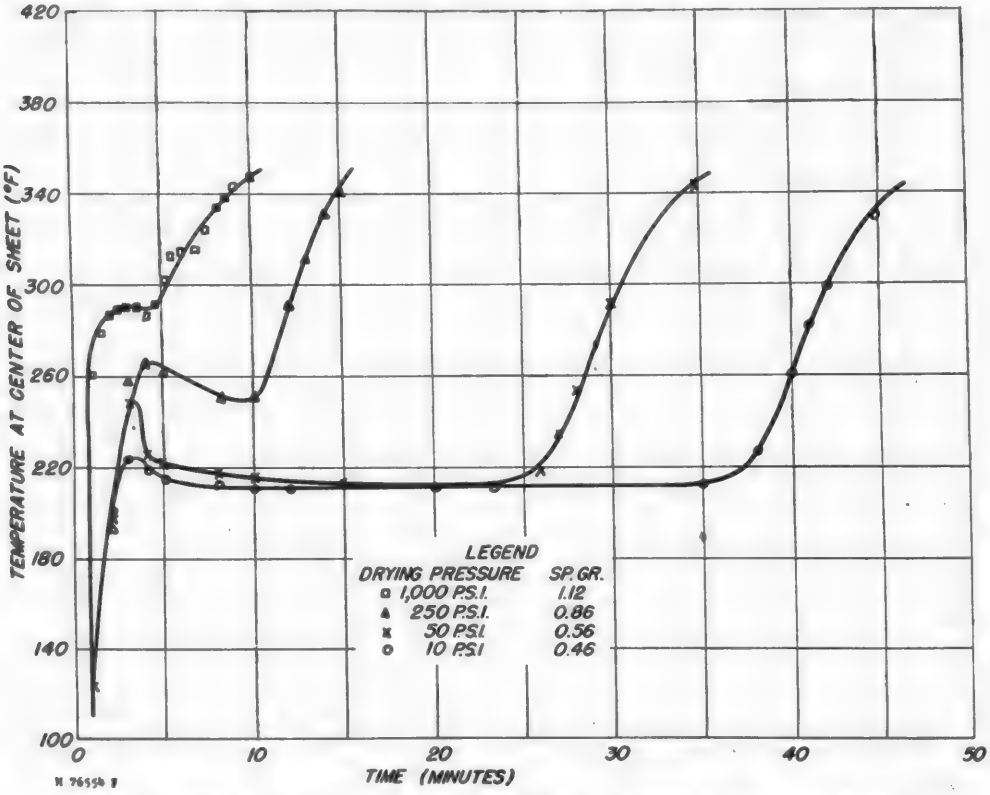

Fig. 9.—Typical time-temperature relationship at midthickness of fiberboards during press drying under several pressures

ure range. Hence, the values obtained at the higher pressures were relied upon for establishing the curve slope.

Factors Affecting Drying Time

The typical time-temperature charts of Figure 9 indicate a rather unexpected initial rise in temperature, which quickly drops to a lower and more stable temperature. This behavior was checked repeatedly on 10-inch square mats. It is believed to be caused by initial formation of steam, which is temporarily trapped in the interior of the mat, but in a short time exit passages develop that permit steam removal at a rapid rate.

The relation of drying temperature to drying time required to press fiberboards to a dry condition at several pressures is shown in Figure 10. The practical significance of this information is that elevated drying temperatures should result in an appreciable decrease in drying time. Since the total amount of heat required is virtually independent of temperature, this implies that greater production may be obtained in a given press time with negligible increase in steam consumption per unit of fiberboard produced.

The data for Figure 11, which shows the effect of sheet weight upon the required press drying time, were derived from other curves and are intended to show, in a general fashion, how the quantity of material per unit area affects the rate of drying under several pressures.

Relation of Drying Pressure and Temperature on Specific Gravity

The curves of Figure 12 illustrate the relation of drying pressure to specific gravity. With this type of pulp, which is comparatively resilient in character, extremely low pressures are

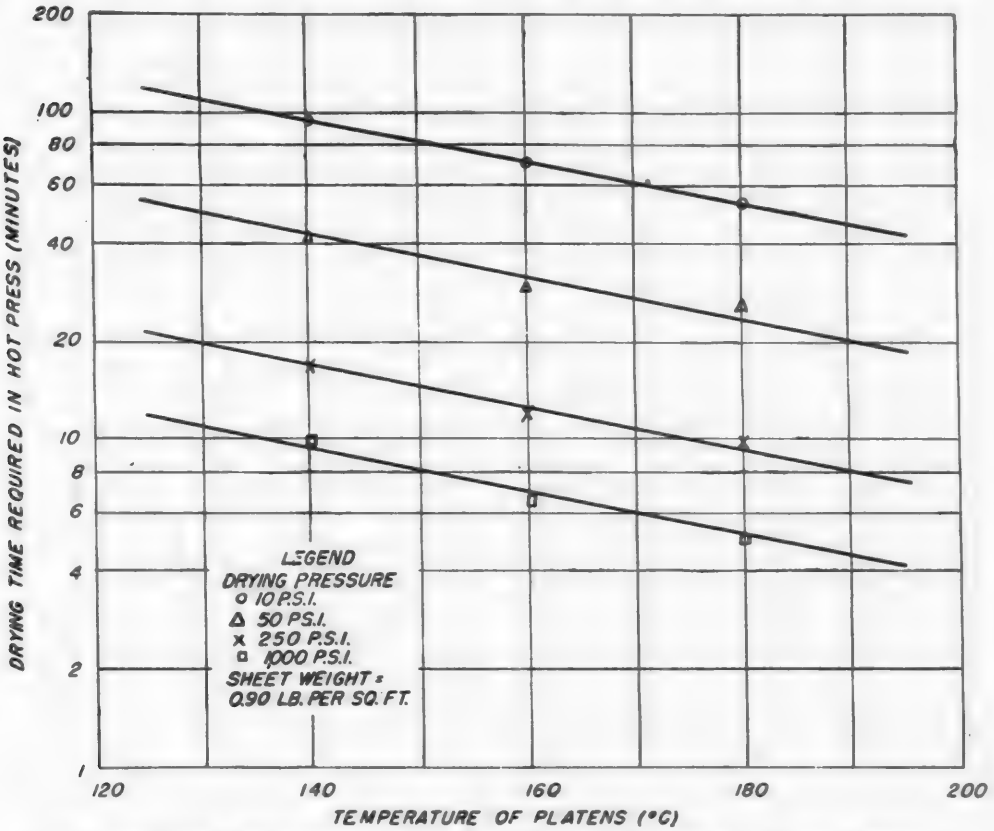

Fig. 10.—Effect of platen temperature upon rate of drying of fiberboards under several pressures. These boards were prepared from 0.005-inch milled fiber.

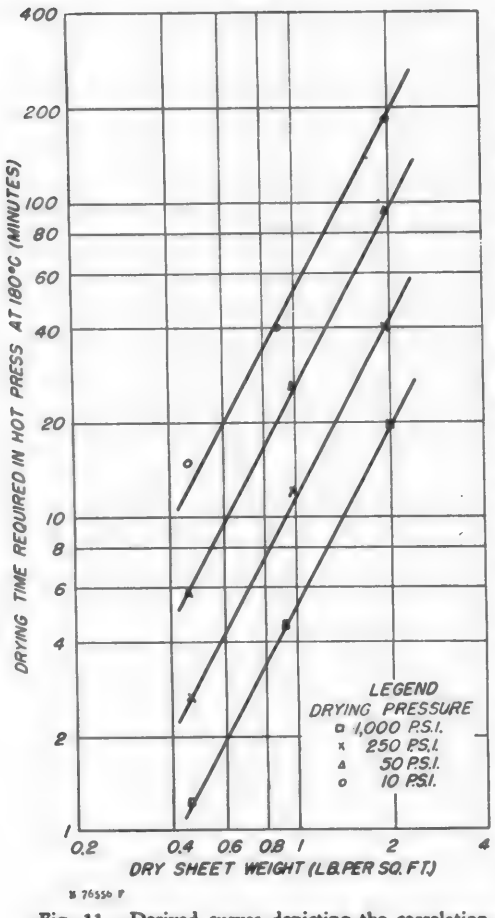

Fig. 11.—Derived curves depicting the correlation of drying-time requirements at several pressures for fiberboards of various sheet weights.

necessary to give fiberboard of the desired insulating quality, and, conversely, specific gravities above 1.0 require very high pressures.

The effect of degree of fiber refinement is of considerably less importance in relation to final specific gravity obtained in press-dried than in oven-dried fiberboard.

Apparently temperature alone has a significant effect on final board density (Figure 13), but when considered in the light of the relationship shown in Figure 14, it is obvious that solids content prior to oven drying is the factor of prime importance. Thus, the means used to achieve a given solids content, whether by appropriate control of dewatering pressure or of temperature, is of secondary importance in the determination of the final specific gravity of the board.

From these data it is apparent that there is an overlapping range of fiberboard density that would permit either press-drying or kiln-drying technique to be used, but at the same time rather definite density limits are also indicated for these drying methods.

Effect of Dewatering Pressures on Specific Gravity

Effect of dewatering pressure upon the specific gravity of fiberboards that were subsequently press-dried under constant pressure is shown in Figure 15. These curves confirm the observations that drying pressure is the determining variable in controlling final board density, although dewatering pressure does have a small but significant effect, particularly on the boards dried at low pressure.

An additional fact of some practical interest was observed during this series of tests. When the wet mats were dewatered at pressures considerably above that used in drying, the water content was sufficiently reduced so that no free water flowed out during the initial hot-pressing cycle, with the result that no extractives or decomposition products were deposited on the caul plates. Polishing and cleaning of caul plates may be greatly reduced by following this practice.

The relative effect of specific gravity and sheet weight in controlling drying-time requirements is illustrated in Figure 16.

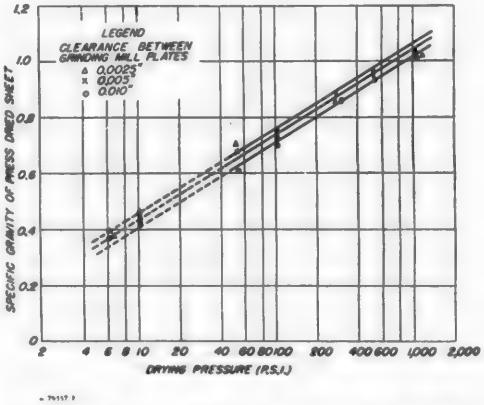

Fig. 12.—Relation of drying pressure to fiberboard specific gravity.

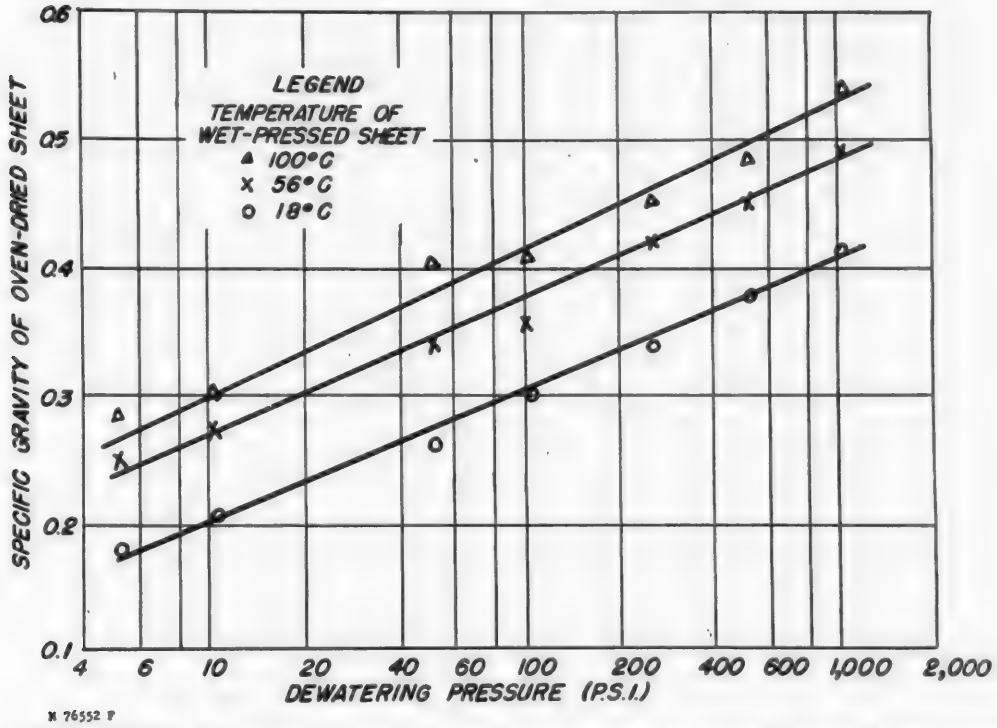

Fig. 13.—Relation of dewatering pressures at several temperatures upon the specific gravity of subsequently oven-dried fiberboards. All these specimens were prepared from 0.005-inch milled fiber.

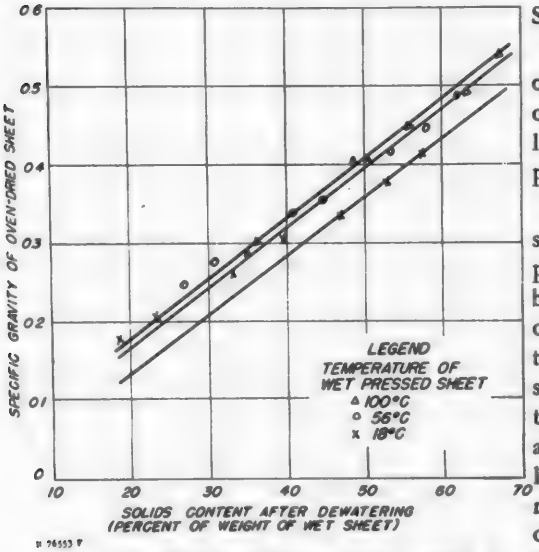

Fig. 14.—Correlation between solids content of pressed fiber mats and specific gravity of oven-dried fiberboards. Mats were pressed at several temperatures and consisted of 0.005-inch milled fiber in all cases.

Strength Tests

The relation of specific gravity and modulus of rupture (Figure 17) presents a rather thorough array of data on these three closely related pulps, and several significant points of practical interest are as follows:

(a) A rather precise relation between density and strength in bending is apparent. For practical purposes the modulus of rupture may be assumed to be directly related to the square of the specific gravity. Thus, after relatively few tests, it is possible to determine the entire strength range potentially available with a particular pulp stock. This, of course, can only apply to fiberboard products prepared in a similar manner and would not necessarily apply to materials that are subsequently subjected to other treatments, such as oil, resin impregnation, or other chemical agents that may alter the nature of the fiber-bonding action to an indeterminate extent.

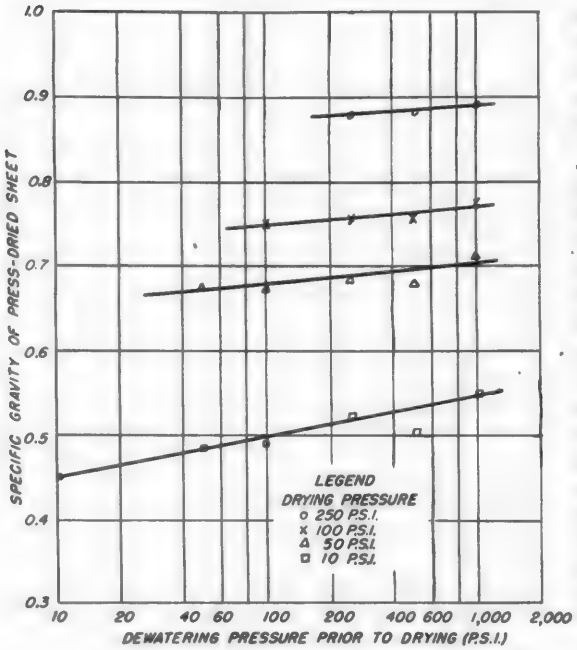

Fig. 15.—Effect of dewatering pressure upon specific gravity of fiberboards subsequently press-dried under constant pressures. All specimens were prepared from 0.005-inch milled fiber.

Since the strength-specific gravity slopes for all three materials are parallel, the general form of equation that may be used in the evaluation of similar fiberboard materials is:

$$\frac{R_1}{R_2} = \frac{G_1^2}{G_2^2} \text{ or } \frac{R_1}{R_2} = \left(\frac{G^1}{G_2}\right)^2$$

where R_1 = modulus of rupture determined
G_1 = specific gravity at test
R_2 = computed modulus of rupture
G_2 = specific gravity at which it is desired to evaluate the material.

In applying the equation, another factor must also be considered—that of moisture content at time of test. The exact magnitude of this factor has yet to be well established, but it is known to have a significant effect on the physical quality of these materials used and, hence, must be taken into account in the analysis of strength test data.

(b) There was a significant discrepancy between the strengths of oven-dried and press-dried fiberboards of comparable specific gravity derived from identical pulp stock. At the present time, however, the experimental data are insufficient to permit a more critical evaluation of the two methods of drying fiberboards of intermediate density.

One approach to an explanation of this behavior might be presented as follows: Those fiberboards subjected to oven drying are exposed to an elevated temperature for a relatively long time and during an appreciable portion of the drying period a large amount of water is present in the fiber. This condition is conducive to a mild degree of hydrolysis, with a consequent reduction of fiber strength. It might be thought that the hydrolytic conditions are much more severe in press drying because of the higher temperatures used; but this also needs qualification, since it is apparent after an examination of the data presented in Figure 13 that the drying temperature of the wet portions of the mat is well below that of the press platens until drying is completed.

Perhaps another explanation of the strength variation between oven-dried and press-dried fiberboards is that in press-drying the surface fibers may be more positively oriented parallel to the plane of the sheet. Since the orientation of the outer fibers is of primary importance in the determinatinon of bending strength, the superior degree of surface fiber orientation in the press-dried sheet would account for a significant increase in strength.

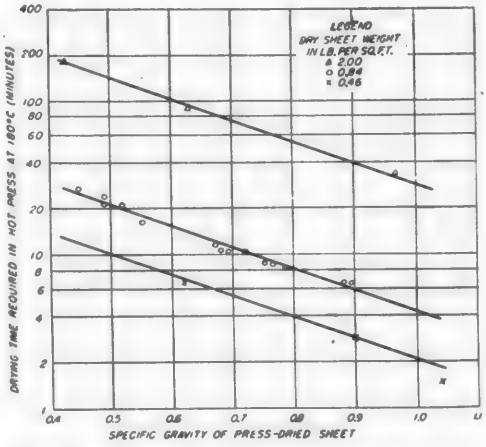

Fig. 16.—Correlation of fiberboard specific gravity and press-drying time required for several sheet weights.

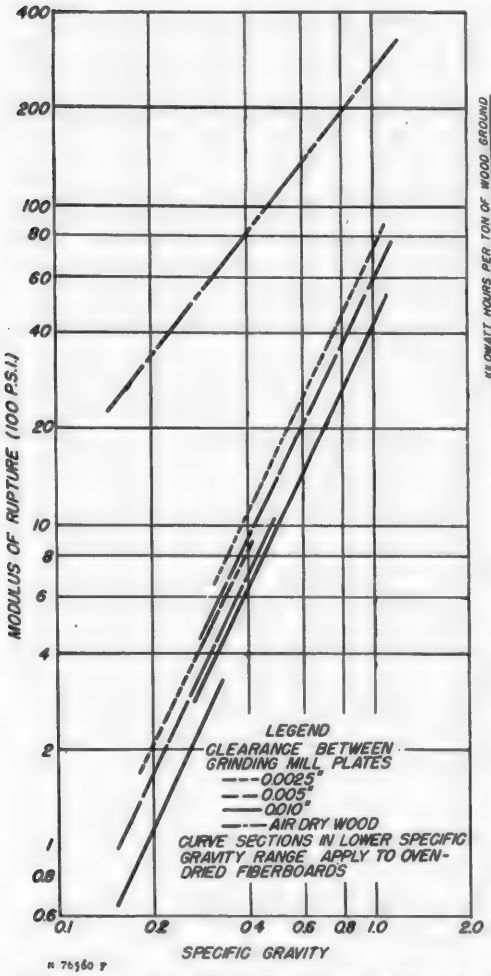

Fig. 17.—Relation of specific gravity of oven-dried and press-dried fiberboards derived from similar pulps to modulus of rupture. The separated portions of each curve in the lower specific gravity range are based on the results obtained from oven-dried specimens. The curve for wood is included for reference purposes only.

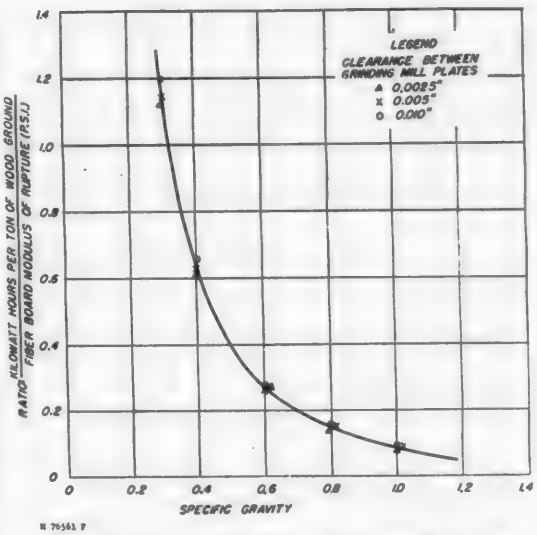

Fig. 18.—Correlation of power consumed in the preparation of similar pulp stocks and the modulus of rupture of fiberboards derived from these pulps. Strength data at several specific gravities are based on curves obtained from a number of tests covering a wide range of density.

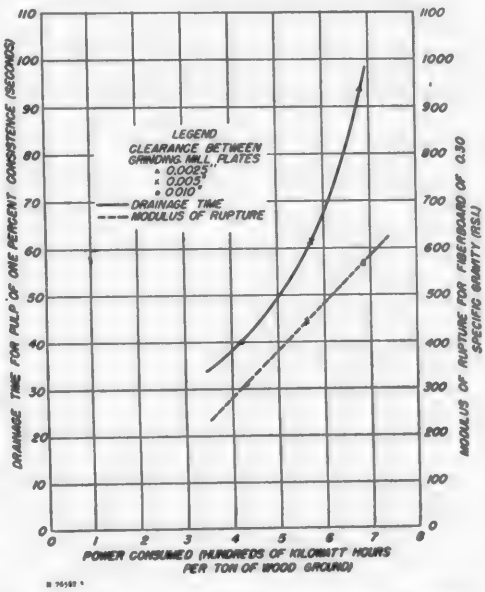

Fig. 19.—Comparison of drainage time and strength of pulp in relation to power consumed in grinding.

The overlapping density range of fiberboards that could conceivably be produced by both of these drying methods is rather limited. Hence, precise comparison of the two methods is not of immediate technical importance.

Figure 18 presents the power consumption and strength relationship. These data are presented primarily to illustrate that these two factors are intimately related functions and that an adequate evaluation of a pulp stock should include a consideration of this relation. Perhaps the principal utility of this type of data lies in its value as background material with which to

compare other procedures in the preparation of fiberboard pulps.

For pulps of the type and range of drainage rates investigated in this study, the power consumed in processing the fiber per unit flexural strength attained in the fiberboard product is virtually independent of the degree of fiber refinement.

The comparative relation of drainage times and the strength of fiberboard pulp stocks to power consumed in fiber processing is given in Figure 19. The essential fact here is that as higher strengths are developed, a disproportionate increase in drainage time results. This type of basic comparison is also of considerable worth in the precise evaluation of a pulp stock and as a relative measure of the effectiveness of stock preparation technique. These data are, of course, exceedingly limited and it was beyond the scope of this particular investigation to engage in a more thorough study of the many processing factors that are known to be of some influence on the quality of the final pulp stock.

The results of the tests to determine the magnitude of the segregation effect are presented in Table 1.

These data indicate that segregation does not have so significant an effect on coarse pulps as on the more finely refined pulps. The magnitude of the effect is not great in any event, however, as even under the extreme procedure used in forming these boards the difference in strength was in the range of five percent for the two coarser pulps and ten percent for the highly refined pulp.

TABLE 1.—EFFECT OF SEGREGATION OF FIBERS DURING SHEET FORMATION UPON MODULUS OF RUPTURE OF FIBERBOARD

Position of filter screen surface in test	Clearance between grinding mill plates (inch)					
	0.010		0.005		0.0025	
	Specific gravity	Modulus of rupture Psi.	Specific gravity	Modulus of rupture Psi.	Specific gravity	Modulus of rupture Psi.
Up	0.58	1,590	0.63	2,430	0.66	3,310
Down	.59	1,550	.63	2,350	.66	3,020

TECHNICAL SESSION III

Tuesday, March 23, 1948, 9:00 A. M.

General Subject: Bark Removal and Utilization

Chairman: Bror L. Grondal, Professor of Forestry, University of Washington, Seattle, Washington *(Past Chairman, FPRS)*

Recorder: Robert A. Cockrell, Associate Professor of Forestry, University of California, Berkeley, California *(Southwest Regional Board Member, FPRS)*

Small Hydraulic Log Barker

C. Stanley Leaf
Allis-Chalmers Manufacturing Company, Milwaukee, Wisconsin

Introduction

FOR many years the pulp industry has sought, through various ingenious devices, to replace the laborious hand method of removing bark from pulpwood logs. To date, no one machine has been able to perform the barking of logs to the satisfaction of all concerned, and numerous mills still resort to hand-peeling.

In recent years many people have viewed the hydraulic barker as a machine which can perform wonders in this important operation; unfortunately, it is often regarded as capable of doing work which is mechanically and hydraulically impossible. With this in mind, this paper has been prepared to assist those in the industry better to understand the principles of one hydraulic barker and what may be expected from its operation.

Construction and Operation

One method of hydraulic barking is designed to clean the general run of reasonably straight pulpwood logs, from 4 to 18 inches in diameter and either 4 or 8 feet long. The term "reasonably straight" does not mean that all sticks must be round and free from knots and irregularities in shape, but refers to the fact that extremely crooked logs, which cannot be revolved on the bed rolls of the machine, cannot be handled to advantage. Bark located about knots, limb ends or other projections on a log is very effectively removed. Tree tops and reasonably straight branches can be barked, although in the case of very crooked sticks, more than one pass through the machine may be required for complete barking. Four-foot sticks, offset as much as six inches, have been barked.

The action of the jets tends to remove the bark in relatively small pieces, which can be easily handled on a conventional conveyor. Due to the fact that the bark does not remain in contact with the water, except for a very short period of time, the moisture pickup is only about five percent. Thus, if the wood has not been water transported, the bark as it comes from the barker is suitable for fuel without the use of a drying treatment.

The capacity of the barker will vary, depending on the species of wood and the seasonal conditions. Records show machine capacities of as much as 18 cords per hour, with a low percentage of rejects. In general, wood which has been subjected to zero or sub-zero temperatures until it is frozen solid can be barked, but with a considerable reduction in capacity. If, however, a hot pond is used to draw the frost, near normal capacity can be attained.

From accumulated experience at several mills, it has been determined that the barker will handle the usual species of pulpwood cut during all seasons of the year at the rate of approximately 1,000 clean sticks of four-foot lengths per hour. This is on wood supplies averaging seven inches in diameter and less.

To handle the logs, the machine utilizes two 24-inch diameter by 10-feet long bed rolls, one cast with flutes and the other with spirals, both rotating in the same direction but at different rates. Thus, both a turning, and a forward movement is imparted to the log. The peripheral speed is independent of the log diameter, and sticks of varying diameters flow through the machine consecutively, end to end, with a controlled and predetermined peripheral speed under the jets.

Each bed roll is driven by a separate motor through a variable-speed unit, with a chain sproket drive to the roll, including a friction clutch which will slip at a predetermined maximum load. The motors and variable-speed

units are located on brackets provided on the cabinet base, where they are readily accessible for periodic adjustment and inspection. If both rolls are driven at the same speed of rotation, a turning movement only is imparted to the log, but if the spiral roll is driven faster than the fluted roll, both rotation and forward motion of the log is attained. By adjusting the speeds of the bed rolls, any desired relationship between rotation and forward motion can be obtained. However, to maintain good barking with maximum capacity, this relationship must be adjusted to suit the species of wood, the average diameter of the log and the condition of the bark, which will depend upon the season of the year during which the wood was cut.

The bed rolls are made up of sectional cast-steel plates, which are accurately machined at the bearing surfaces and balanced to assure rigid balance. The plates are fastened to supporting heads by bolts and locking nuts in such a way that they may be removed and replaced without removing the bed rolls from the cabinet. The bed-roll bearings are of the sealed self-aligning roller type and these, as well as all other bearings on the barker, are located on the outside of the machine.

Within the barking compartment, three spring-loaded baffle plates bear on the upper surface of the log, with pressure sufficient to hold the logs in position in the roll crotch and under the jets, but not great pressure to prevent rotation or forward motion. The pressure of the baffle on the log is controlled by a spring-loaded air cylinder, which also cushions the baffle as it drops to a smaller diameter stick. Heavy pipe guards and guide plates, running the length of the cabinet and above the bed rolls, prevent crooked sticks from completely leaving the rolls should they become displaced, and return them to the area covered by the jets. Hinged side baffles keep the bark and splashing water within the cabinet, and direct them to the hopper for waste bark and water. A sheet rubber shield located inside the housing and directly over the hopper discharge prevents excessive water splashing out of this discharge. Pressure tips placed at the top of the cabinet direct the jets downward into the crotch of the bed rolls.

Underneath the barking compartment, a heavy sheet-steel hopper is provided to deliver the bark and water into either a low-head screen or the conventional bull screen with drag chain. This hopper is so designed that the discharge may be towards either the feed or the discharge end of the machine.

A feed cabinet is provided to deliver the wood to the main barking cabinet. A special wing-type feed chain receives the logs from the conveyor that delivers them from the yard. This chain centers the logs, regardless of diameter, so that they will enter the bed-roll crotch upon reaching the main cabinet. The wings of the chain are designed with the same radius as the bed rolls. A spring-loaded air-cushioned baffle plate assists in holding the logs in place on the feed chain, while they are engaged by the bed rolls. The speed of the feed chain is synchronized with the forward motion of the sticks on the bed rolls in the barking compartment. The independent motor and variable-speed unit, which drives the feed chain, is located on top of the feeder cabinet.

Limitations

One would be inclined to believe from a description of the machine that exceptional results should be obtained. However, certain mechanical and hydraulic principles present some limitations.

Assuming that sufficient water is available and at a suitable pressure to remove a swath of bark 12 inches wide, a 24-inch diameter log is in the crotch of the 24-inch diameter rolls, and the spiral roll has a lead of 12 inches, 50 rpm. on the fluted roll has been found to produce a peripheral speed which results in good barking. For every revolution of the fluted roll, the log revolved once, and a forward travel of 12 inches must also be obtained if waste of energy by overlapping the jet onto surfaces having already had their bark removed is to be avoided.

If both rolls rotate at the same rate, no forward motion of the log takes place, inasmuch as the spiral only rolls itself along the surface of the log. However, if the rate of rotation of the spiral roll is increased above that of the fluted roll, a forward motion is obtained. With the 12-inch lead on the spiral

roll, this roll must be rotated at 100 rpm. to provide a forward motion of 12 inches for each revolution of the log. This combination of ratio of rotation of the rolls produces the best results possible for logs of this diameter.

When a 12-inch log lies in the crotch of the rolls, the same peripheral speed must be maintained, consequently the 50 rpm. on the fluted roll remains satisfactory. However, this speed rotates the smaller log twice for each revolution of the fluted roll; yet, its forward motion remains at 12 inches, as for the larger log. In other words, the spiral roll needs to be increased in speed to 200 rpm. if to prevent overlapping of our jet.

Not only is there an energy loss due to variations in diameters of logs fed to the machine as indicated by the example cited above but, it is found that with a given roll setting the logs of smaller diameter travel through the machine noticeably more slowly than do the larger logs. This is only natural when one considers that the neutral and geometric axes of a log do not coincide. The smaller the diameter, the greater the chance for these axes to vary greatly, because any small projection or sweep on or in a smaller log has materially more influence on the neutral axis location than a similar irregularity in a larger log.

The foregoing would be of little importance, if the rate of rotation of the smaller wood were not so much greater than the larger logs. The smaller logs thus have a greater tendency to be lifted from the rolls by these various forces and do not carry sufficient weight to counteract this lift. This, then, increases the slippage and their rate of progress through the machine is further reduced below that of the larger logs.

Obviously, any recommended roll speed will be a compromise. It is fortunately not necessary to have complete coverage of the surface during most of the year to get 100 percent bark removal. During the easy barking season, the removal of bark in one area forces water beneath the bark on either side of the area covered by the jets. The resulting pressure lifts additional bark from the surface. Thus, if roll speeds are set to produce 100 percent coverage of pieces of the average diameter, all bark will be removed from the larger pieces.

While the setting of rolls for the average diameter performs satisfactorily in summer operations, it does not prove out when the bark tightens up. On wood cut at other times than spring and early summer, complete coverage of the surface is necessary, along with a slight increase in pressure. Where 650 psi. is satisfactory during easy barking seasons, 800 psi. is required on winter-cut wood.

Having obtained the increased pressure, one of two things must be done to assure satisfactory results either decrease the rate of travel to eliminate the barber pole effect on the larger logs, or increase the quantity of water. The increased water flow must come not from enlarging existing orifice areas but rather from additional orifices. Thus, if three orifices are sufficient during summer months, four or five may be necessary on winter-cut wood. The use of additional orifices is much the preferred method, as a constant capacity can be maintained the entire year.

Conclusions

The hydraulic barker was not designed as cure-all for barking problems. Rather, it was developed for the multiple purpose of removing the bark, thoroughly cleaning all the dirt from around the projecting knobs and irregular surfaces of the log, and delivering the log from the machine without brooming the ends.

Depending upon the age of the mill and its modernness, and the type of wood used and grade of pulp produced, interesting savings can be made by the avoidance of brooming, sawkerf and chipper losses. Hydraulic barkers are of particular value in producing wood that is not broomed and, therefore, the pulp will be much cleaner. By means of the jets of water, field dirt, fly ash, etc., are removed and, if the wood being barked is seasoned and not green, all the advantages of wet-drum barking are offered without its disadvantages. The handling of hardwoods that have been stored in the yard until the bark has become set and the treatment of frozen wood of all species, in which the formation of ice in the bark may cause it to adhere to the wood, are of particular significance in this form of barking.

Do not misinterpret the comments about the removal of frozen bark as pertaining solely to bark having a coating of ice on its surface. Its removal when frozen internally is done, however, when the surface is coated with ice. It should not occasion surprise if the surface coating increases rather than being removed.

Capacities of the machine range all the way from 7 to 18 cords per hour, with corresponding operating costs of $1.23 to $2.68 per cord. These cost figures include operating labor, maintenance labor, maintenance parts, and power. Thus, it is necessary for individual mills to study their requirements to determine whether saving, simplicity of operation, first cost, and space savings would reduce their overall wood-room costs.

Summing up, it may be said that hydraulic barking offers the industry seven principal advantages. *First,* it materially reduces wood loss; barking logs up to 18 inches in diameter and up to 8 feet in length with elimination of one or more saw cuts. *Second,* it increases production, because logs are fed into the barker end to end in a continuous stream for consistently high capacity. *Third,* it saves valuable wood room space, because of its compactness and the manner in which it simplifies the barking cycle. *Fourth,* it permits utilization of the bark as a fuel or a by-product, because the high-speed operation of hydraulic barking keeps the moisture content of bark low. *Fifth,* it eliminates several costly machine operations required with other types of barking, and many unnecessary hand operations. *Sixth,* hydraulic barking is versatile enough to permit barking of practically all species of logs, regardless of their shape or condition. It barks western fir, hemlock, spruce, southern pine, poplar and all hardwoods. Condition of wood is no particular obstacle, because hydraulic barkers successfully handle frozen wood, dozey wood, knotty wood, and reasonably crooked wood. *Seventh,* by means of hydraulic barking, it is possible to bark many logs 100 percent clean; with no dirt, no surface rot, no brooming of log ends and no wood loss, assuring pulp of a higher quality and, in the long run, paper products of higher quality.

Discussion

Mr. Vance P. Edwardes (International Paper Company, Palmer, N. Y.): Mr. Leaf has presented a very fair analysis of the small log hydraulic barker which most certainly filled a vital need during the war, when mills accustomed to receive barked wood were suddenly confronted with three-fourths of their supply being shipped in the rough. As he points out, the barker cannot work miracles, but it can and does do a good job if properly operated. By that is meant supplying wood without any large gaps between sticks, wood as nearly as possible of uniform size, and various wood species being barked separately.

Unless the conveyor lay-out is so designed that wood is delivered to the barker with not more than six inches separating the bolts, loss in capacity will result. Since there is a relatively narrow limit to the optimum distance from the tip of the jet to the surface of the log, the barker will do a better job if that limit is not exceeded. Very often, this is impossible. Since the ease of bark removal varies with species, it is obvious that the different species should be barked separately.

There is one poor feature to wood hydraulically barked, namely, the production of long hairs or slivers left attached to the surface. This does not appear on all sticks and may possibly be due to incipient sap rot, but it is felt to be undesirable.

Dozy sticks will almost disappear in the barker, and it does a nice job in cleaning around knots, although it does not always remove the inner bark.

Perhaps the following figures of a year's operation in a northern New York mill may be of interest:

Connected horse-power	432½
Actual horse-power	375
Maximum cords per hour	10 gross
Monthly avg. cords per hour	8¾ gross
Rejects	15%
Sticks per cord	80
Nozzle pressure	800 lbs.
Nozzles	3
Life of nozzles	6 months
Life of C. I. bed plates	12 months

Mr. D. T. Jackson (Hammermill Paper Company): The following comments are based on our experience:

1. Early barkers had mechanical bugs which are now being corrected.

2. These barkers are used by us on small logs and mixed feeds of spruce and balsam; 3 to 14 inches in diameter, with a possible average of 8 inches. When a small log follows a large one, there is a tendency for the small log to ride over the larger and cause a jam.

3. This type of barking has not been satisfactory on either green or dry poplar or aspen. Green bark is difficult to remove and production is low. Dry wood has "inner" bark hard to remove.

4. Effluent from the hydraulic barker is difficult to handle, as it is full of finely divided matter. Screens so far tried have not been adequate. Recirculation of water is essential, but no information is available as to the quality of water which the equipment will tolerate. Disposal or treatment of effluent will have to be solved in states where pollution is a problem.

Mr. E. W. Fobes (U. S. Forest Products Laboratory) ; I should like to ask Mr. Leaf several questions. What ultimately makes the bark separate from the wood? Is it the weight of the water? Have you tried injecting steam into the water stream, to determine the effect of elevated water temperature on barking? Finally, how much of the cost of operation is represented by labor?

Mr. Leaf: It was generally felt that erosion of the bark was the cause of its removal. However, after witnessing operations of various barkers, both on summer and winter wood, it has become apparent that erosion is not the answer. Hydraulically we can build up a pressure within the boundary between the bark and the wood in two ways; either by momentum, where mass or weight is generally considered important, or by energy, where velocity is the controlling factor. In either case the force set up in the boundary must be sufficient to shear along this boundary, yet not so great as to penetrate into the wood and begin to lift usable fiber from the log's surface. This action can be better visualized if one considers it in the light that a horse actually pushes a wagon even though he is in front of the vehicle.

Whether momentum or energy individually produces the results obtained, no one can say for sure. During the easy barking season quantity of water seems to be more important than high velocities, while in the winter season velocity takes over as the important item. It undoubtedly is a combination of both factors, as neither a large volume of water with a slow velocity or a very small volume of water with a very high velocity will produce the desired results.

The injection of steam into the water stream has not been tried, to determine the effect of water temperature on barking. We have considered the application of an inert gas into the water stream for the purpose of dispersing the jet of water. This dispersal has been obtained, however, by a properly designed jet, and no studies of the action of either steam or gases have been made.

Unfortunately, we do not have any figures on operating costs, showing a breakdown as to direct labor charges. We might say, however, that the average barker produces around 75 cords per 8 hours and the number of men required for its satisfactory operation depends upon the individual installation. In two installations the barker is operating with only one man, but the average requirement would be two men, one for proper feeding and operation of the barker, and the other at the discharge end for the grading of logs.

Dr. Hereford Garland (Michigan College of Mining and Technology): Does your company have a slab barker of this type?

Mr. Leaf: We are presently working on a design incorporating changes found necessary from tests on the West Coast. Complete information will not be available until September 1.

FOREST PRODUCTS RESEARCH SOCIETY

Mechanical Methods of Bark Removal

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Production of lumber from logs entails considerable "waste" of good wood in the form of trimmings, slabs, and edgings. Large sawmills have profitably converted this material to pulp chips after first removing the bark, but the smaller mills have not followed suit, partly through lack of adequate equipment.

This paper presents a listing and description of various types of bark-removing machinery, as compiled in 1947 for the Forestry Division of the Ontario Research Commission. The barking devices described are divided into three types, using (a) cutting knives, (b) rubbing friction, and (c) hydraulic erosion. The problem of bark removal in the small sawmill is discussed and the requirements for suitable barking equipment are outlined.

Canadian prices and the names of Canadian suppliers are given in some instances, since the purpose of the original report, much of which is herewith reproduced by kind permission of the Ontario Research Commission, was to provide information specifically for the Ontario sawmill operator.

Introduction

IN EASTERN Canadian sawmills the average yield of lumber is about 50 percent by volume of the spruce logs entering the mill. The other 50 percent, known as "waste", consists of approximately 15 percent sawdust, 5 percent trimmings, and 30 percent slabs and edgings.[1]

There are various methods of converting sawmill "waste" into marketable by-products,[2, 3, 4] but the one most readily applicable is that of converting trimmings, slabs, and edgings into pulp chips for the sulphite and sulphate paper processes. For this purpose the wood must be "bark free", *i.e.*, have less than 1 percent of bark, by volume, in the chipped wood.

On the West Coast, the large sawmills either remove bark from the logs before sawing, or from the slabs after sawing, and because of larger average log diameters have been able to develop economic hydraulic barking methods.[5, 6] In the Price Brothers' mills of Quebec sawlogs are barked in Waterous friction barkers prior to sawing and the slabs and edgings are chipped for pulp. At Cabano, New Brunswick, a 150,000 bd. ft. per day sawmill of the Fraser Company uses "buzz barkers" to clean bark from the slabs and edgings before chipping.

Although the large sawmills have reduced waste to a minimum, there is a large amount of good wood not utilized in the many small mills. This may be partly due to backwardness on the part of the small mill operator, but the cost of barking, chipping and transportation in relation to the price paid for chipped wood, as well as the availability of the additional labor required for barking and handling, are factors that must be carefully considered. The question of whether a sawmill should sell its waste to the pulp mill as slabs or as chips is discussed in reference.[3]

To ascertain the best method and form of equipment for bark removal in the utilization of sawmill waste, the information that follows was compiled. Hand methods and barking devices used by the pulpwood industry and in post peeling have been included to give a more complete picture. The various methods are classified under three headings: A—those employing knives, B—those using mechanical friction, and C—those using hydraulic erosion.

Knife Barking

A-1 Hand barking by draw knives is applicable for either logs or slabs. No capital outlay is required but, as the output is low, the labor cost is high and a large working area must be provided. Some good wood is removed with the bark.

A-2 Sap-peeling by hand is performed in the woods within a day or so after a tree is felled. The bark is nicked with an axe and then removed in sheets, using a blunt tool known as a spud. The operation is slow (five cords per man per day), the woodsmen do not relish sap-peeling as an occupation, and its use is

restricted to the early summer months. However, the log is left extremely clean with no loss of good wood.

A-3 A "buzz barker" consists of a waist-high, 3000 rpm. horizontal spindle, on either end of which is mounted a head with four parallel knives. The cutter heads are enclosed with only the top edge projecting, so that a slab or edging drawn across it will have the under side shaved (Figure 1). Bark is removed from half the length of the slab

Fig. 1.—Battery of Buzz Barkers.

before turning it end for end to do the other half, and the slab must be turned over for frequent inspection during the operation. As much as 15 percent, by volume, of good wood may be lost by cutting below the bark, and slabs thinner than 5/8 inch are not strong enough to be barked.

An edging requires about 20 seconds to bark and an 8 inch-slab about 30 seconds. One operator can bark 1¼ to 1½ cords of slab wood per day, which corresponds to about 6000 board feet of sawn lumber, or 180 logs. Since there are two cutter heads, this represents half of the machine output.

The buzz barker requires two operators and one man to feed to them, as wood is selected from the trash conveyor.

Buzz barkers are made by Waterous Limited, of Brantford, Ontario, and the model having a 5 hp. motor mounted directly on the spindle sells for $725.00.

For very wide slabs a disc barker may be used. In this machine the knives run radially outward on the rotating disc, the slab being held against the face of it. Also made by Waterous Limited, a 52 inch diameter disc barker sells for $900.00.

A-4 The Efurd Machine & Welding Co. of Bossier City, Louisiana, publishes a bulletin describing its machine for peeling poles. The pole is rotated on two bed rolls, while two rotating cutter heads, mounted in tandem for roughing and finishing, respectively, are pressed downward on the top surface of the horizontal pole, as shown in Figure 2. Three electric motors are used, and the capacity is given as a pole per minute.

A-5 The J. & C. Rosser, made by H. L. Crouse of Crouseville, Maine, and handled in Canada by Creighton & Smith Motors of Fredericton, N. B., is intended for barking pulp logs four feet in length. The log rotates on an idler roller and a powered cutting roller having three knives that project 1/16 inch. A power-driven toothed wheel is pressed down on top of the log, causing it to rotate and to feed through the machine.

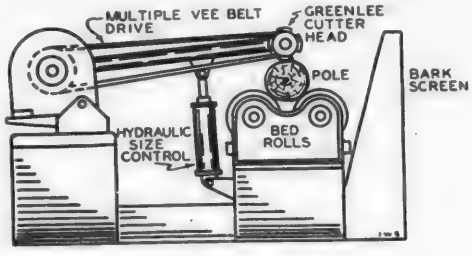

Fig. 2.—The Efurd Pole Peeler.

Total horsepower is 10 and, with straight wood and a good operator, the capacity is 1½ to 2 cords per hour. The price is $1400.00 in Canada.

A-6 A machine that is similar to the J. & C. Rosser, but of simplified design, is known as the Peppy Peeler for pulpwood.[7] The pulp log rests on a power-driven cutting head and an idler roll, being rotated and fed through by a toothed wheel, power-driven, pressed

on the top of the log by foot pressure (Figure 3).

Powered by a 6 hp. Briggs & Stratton engine and operated by two men, a pulp log is claimed to be peeled in less than 30 seconds.

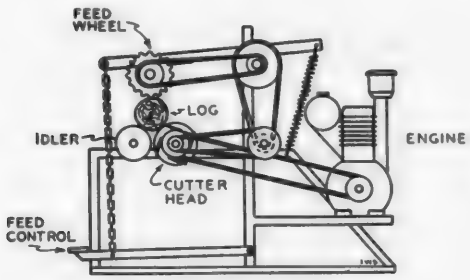

Fig. 3.—The Peppy Pulp Peeler.

Friction Barkers

B-1 One of the older friction barkers is the Thorne barking system for pulpwood. As described in bulletin 1729 of the Sawmill Department of the Allis–Chalmers Manufacturing Company, it consists of three sheet-metal pockets wide enough to accommodate the pulpwood length, *i.e.*, 4 ft., 8 ft., 12 ft., etc.; through the bottom of each extends a pair of rotating cams which serve to agitate the pulpwood in the pockets. Water is sprayed on the logs as they rub against each other and they gradually work from pocket to pocket, finally emerging at the discharge end. (Figure 4.)

This barker is used with water-stored wood and is more effective the longer the wood remains in storage. Inspectors are stationed at the discharge conveyor to return incompletely barked wood, which varies from 25 to 70 percent of the output, depending on the length of soaking time.

Forty-five horsepower are required for the four-foot pulpwood size, with the cams turning at about 13 rpm. This gives a capacity of about six cords per hour for effective barking, but 16 cords per hour can be put through.

B-2 Drum barkers have been used extensively for pulpwood in the short lengths. The drum barker consists of a horizontal drum made up of welded slats, 10 to 12 feet in diameter and 30 to 45 feet long. The logs are rolled against each other on the inside of the drum as the drum rotates, and water is sprayed on them to wash the bark away.

A 12 by 45-foot drum barker built by Waterous Limited of Brantford sells in Canada for $51,000, equipped with a 125 hp. motor. The capacity, with water-stored wood, varies from 20 to 40 cords per hour, depending on the length of soaking. On green wood the capacity is much less.

A great disadvantage of the drum barker is "brooming" or splintering at the ends of the logs as dirt lodging in the splintered ends is detrimental to good paper manufacture.

B-3 The friction barker for sawlogs, built by Waterous Limited of Brantford, uses a large

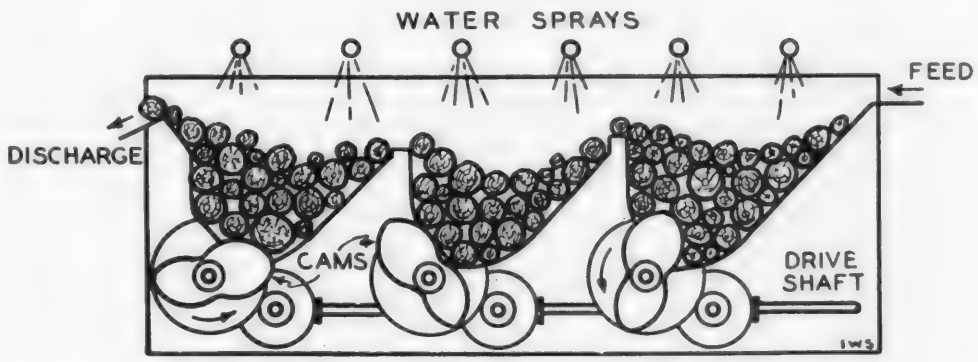

Fig. 4.—The Thorne Pulp Barker.

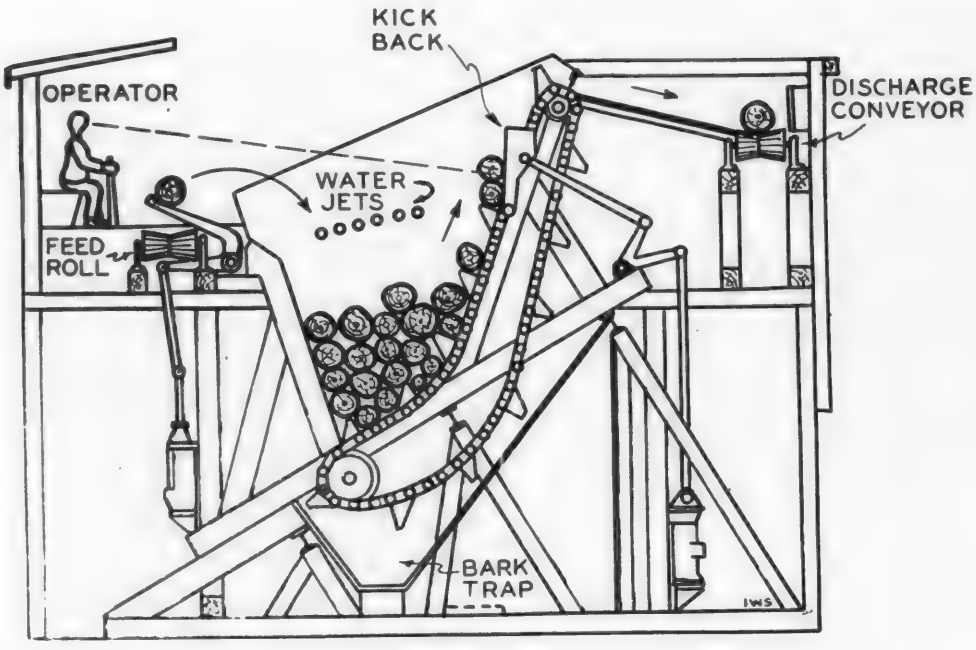

Fig. 5.—The Waterous Sawlog Barker.

single hopper, wide enough to accommodate 18-foot logs, and a set of three or four chains to roll the logs against each other in the hopper (Figure 5). Water jets spray the logs to wash off the loosened bark. The chains continually bring logs up from the hopper, but these are watched by an operator and are mechanically kicked off the chain dogs, back into the hopper, if not completely barked. For clean logs the kickers are withdrawn so the logs can pass up and out to the discharge chute.[8] Figure 6 is a photograph of the logs coming up on the chain at the top of the picture.

Barking is done on water-stored logs and the results are much better for logs that have been in the water several months. Logs under 10 feet in length or 5 inches in diameter tend to jam and break in the machine and are avoided, although they could be handled satisfactorily in a smaller unit.

The chains require 65 hp. for the barking operation, the associated log haul and conveyors take 35 hp., and the pump 75 hp. One operator feeds logs to the log haul, a second controls the infeed rolls to keep the hopper filled, and a third man controls the kickers. The bark is dewatered on a screen and is then either conveyed to a pile or carted away for fill material.

The average output over a season is 300 logs per hour, or about 22 cords per hour.

Present cost of this Waterous sawlog barker, without installation or conveyors, is $26,500, and maintenance cost per year is $2,000 to $3,000.

B-4 The Nekoosa Portable Wood Peeler (9), is made by the Nekoosa Foundry and Machine Works, Inc., Nekoosa, Wisconsin and is described in their bulletin 57. It is intended for cleaning pulpwood, three to 12 inches in diameter and four to eight feet long, during the peeling season and is drawn by tractor to the cutting site in the woods. (Figure 7.)

The pulpwood rotates and passes between three rollers: an idler roll, a power-driven roll carrying several sets of pivoted hammers that strike the bark tangentially, and a

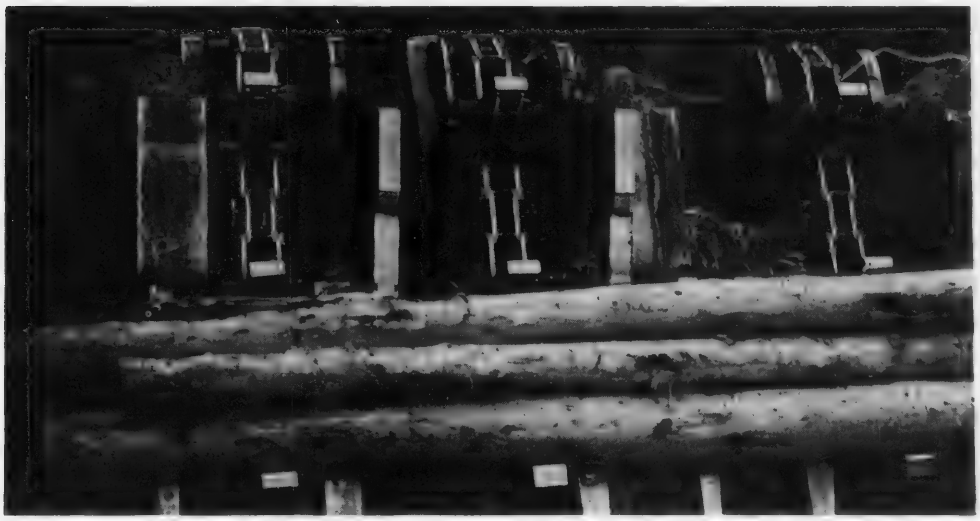

Fig. 6.—Barked logs from the hopper of a Waterous Sawlog Barker. Note the kick backs between chains, and the water spray from the sides of the hopper.

powered feed-roller set at an angle to cause both advance and rotation of the log. Logs are fed to the machine on a roller conveyor by three men, and are taken from the discharge rollers, for piling, by another three men. An operator sets the hammers for each size of log and adjusts the pressure to suit the tightness of the bark, and another man keeps the bark disposal conveyor cleared. Green wood is cleaned very effectively.

Power is supplied by a 30½ hp. gasoline engine. An output of six to seven cords per hour is claimed, but on an actual run of spruce pulp wood five cords per hour were averaged.

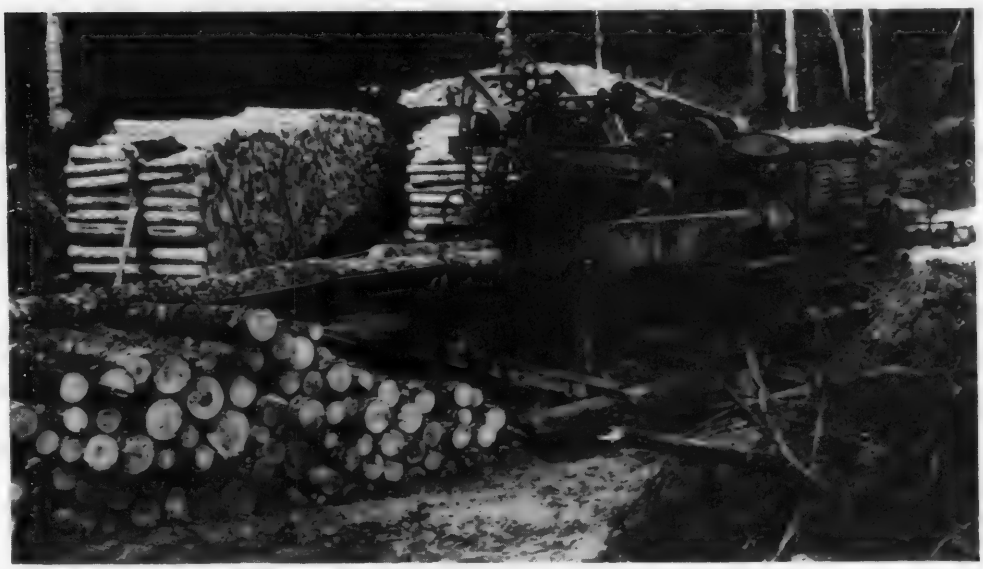

Fig. 7.—The Nekoosa Portable Wood Peeler on location. Note the clean pulp wood in the background.

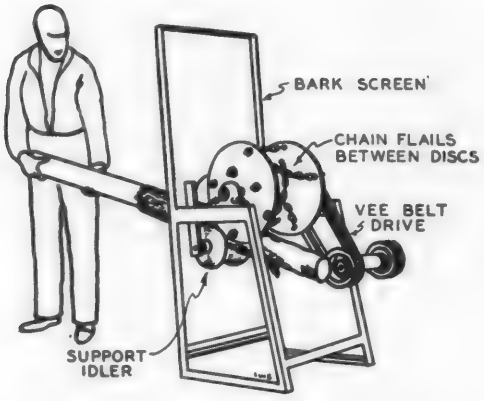

Fig. 8.—The Lowther Pole Peeler. (The driving engine is not shown.)

Cost of the Nekoosa barker in the United States is $9,000.

B-5 The Lowther Post Peeler, built by Harry A Lowther Co., 141 West Jackson Blvd., Chicago, Illinois, is a light, single-operator machine for taking bark off fence posts. The operator holds the post at one end, rests it on an idler roller and, by pressing down on the held end, forces the free end upward against a rotating cylinder of chains (Figure 8).

Friction of the chains removes the bark as the post is drawn back and forth, and rotated. After cleaning one half, the post is turned end for end to do the other half. The size of log handled depends on its weight, but seven-foot logs up to 8 inches in diameter may be cleaned.

The machine has an all-welded frame, with the cylinder shaft running on ball bearings, and it weighs only 300 pounds.

Six horsepower are required and the capacity is given as 200 to 600 posts per day per man, or less than two minutes per post.

Price of the machine in the United States is $280, with engine.

B-6 The Click Post Peeler, built by Mr. Click Mathewson of Lake City, Florida, also uses a rotating drum of chains, but the idler roller is elevated so that the post passes above the cylinder. The weight of the post is used in holding it against the chains.

The capacity given ranges from one pine post per minute to two minutes on oak and ironwood. The cost of the machine with 6-hp. engine is $450 in the United States.

B-7 Another friction type of barker employing chains is the Astrom barker[10], first developed in Sweden and now under development in America by American Defibrator, Inc., Chrysler Building, New York.

As shown in Figure 9, chains stretched across a rotating wheel are wrapped around the log as it is fed, without rotation, through the wheel. Because of the wheel rotation, the chains wear through the bark to the wood and feeding of the log causes the bark to peel off in strings.

The wood is peeled very clean without damage, even around knots and irregularities, and crooked wood offers no difficulty. The chains must be opened as a new log enters and a few inches may be left unbarked before the chains are reclamped.

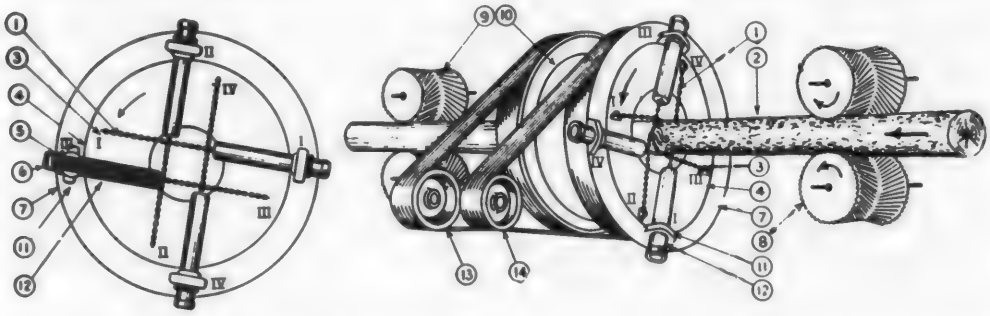

Fig. 9.—Diagram of the Astrom Log Barker. 1—Barking chain; 4—inner wheel; 5—chain tension spring; 7—outer wheel; 8 and 9—power feed rolls; 13 and 14—drive pulleys.

The standard machine takes logs up to 15 inches in diameter and of any length. The feed rolls are powered so that one man can operate the machine. Thirty horsepower are required for operation and the capacity is given as 10 to 18 cords, or 300 logs, per hour of material 17 feet in length and up to 15 inches in diameter.

As the machine is still in the development stage, the actual price is not available, but an estimate of $20,000 was given in the Canada Lumberman issue of August, 1946.

Hydraulic Barkers

C-1 The Allis–Chalmers Streambarker (*11*) consists of two power driven bed rolls, one fluted for rotation of the log and one spiralled for feeding the log, and three high-pressure water nozzles. The log rotates on the bed rolls while the jets, from the nozzles directly above, impinge on the top surface to erode the bark away (Figure 10). The entire assembly, including a short feeding and centering conveyor, is enclosed in a water-tight housing, on the outside of which are mounted the motors and variable-speed drives.

The Streambarker can be arranged to take logs up to 8 feet in length and 4 to 18 inches in diameter. The feed is continuous, with a few inches between successive logs to prevent crowding, but without any need for continual log size adjustment.

Bark is removed effectively, along with dozey wood and embedded dirt, without damage to the sound wood. Although the log rotates during barking, some crookedness and irregularity can be tolerated. The streambarker does not require softening of the bark by water storage and, when used on dry wood, the removed bark can be burned without the use of a bark press to eliminate excess moisture.

The bed rolls and feed conveyor are powered with a total of 18 hp. A four-stage pump uses 350 hp. to supply 550 U. S. gpm. of water to the nozzles at a pressure of 650 psi. A capacity of 8 to 15 cords or 1000 sticks per hour of wood four feet long and seven inches in diameter is claimed.

The price of the Canadian Streambarker is $28,000.

C-2 A hydraulic slab barker has been built by the Puget Sound Pulp and Timber Company at Bellingham, Washington.[6] It is designed for slabs 12 inches wide and not less than two feet long.

Bed Rolls and hold-down rolls carry the slabs, bark upward, beneath three water jets at 1100 psi. The feed rate is given as 60 to 180 feet per minute with an output of five cords per hour. A six-stage Worthington pump requiring 400 hp. is used.

C-3 A hydraulic log barker is used by the Powell River Company B.C., for 26-foot logs

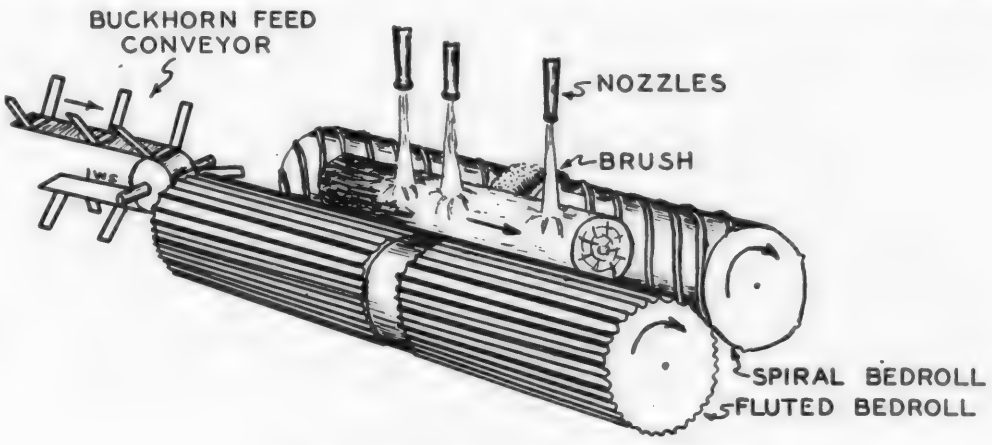

Fig. 10.—Diagram of the Allis–Chalmers Streambarker.

up to nine feet in diameter.[12] In this machine, a single nozzle is moved the length of the log at 40 feet per second by a "shot gun" steam cylinder. The log is indexed between passes under the control of an operator, who views the operation through a window in the casing.

Two five-stage pumps supply water at 850 psi. and a three-stage booster pump can be used when necessary to obtain 1250 psi. Each pump requires 500 hp. and, in addition, steam for the 12 inch diameter, 31½-foot stroke, carriage piston must be supplied.

The barking operation requires 30 to 40 seconds.

C-4 The Soundview Pulp Company of Everett, Washington, has developed a ring-type hydraulic barker.[13] Without rotation, a log up to 30 inches in diameter is passed through a ring of 36 nozzles delivering water perpendicularly against the log at 1150 psi. Each nozzle may be controlled separately and for smaller logs only part of the ring need be used. For logs above 36 inches and up to 60 inches in diameter, the ring separates into three segments and two passes of the log, with a 60 degree index, are required. Figure 11 shows the segments in the separated position.

Water flow is controlled by a trigger and is used only while a log is in the ring. By using a pressure accumulator, charged during non-spraying periods, a water capacity 250 percent greater than the pumping capacity is obtained.

Two pumps, each 1500 U. S. gpm. at 1150 psi. and requiring 1250 hp., are provided. Average barking speed is 180 feet per minute, giving a capacity of about 35,000 board feet per hour.

Location of the Barker

Bark removal at the cutting site results in easier water driving of logs and cheaper truck haulage, since barked logs contain less moisture. Separation of bark from the wood is easier during the four months of the sap-peeling season and this period can be extended with trees that are chemically killed before cutting.

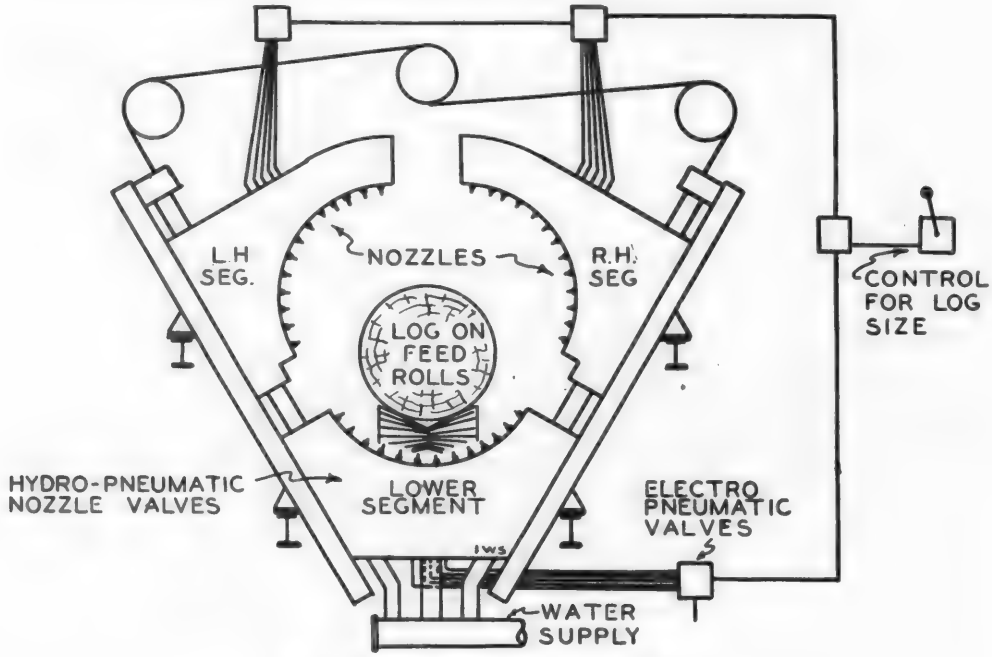

Fig. 11.—The Soundview Hydraulic Ring Barker.

However, it is more difficult to secure labor for barking operations in the woods, and the discarded bark becomes a fire hazard. An adequate level space for the operation of a barking machine near the cutting site is not easily found. Winter-cut wood cannot be sap-peeled.

Bark removal at the sawmill, *before* sawing, provides a number of advantages such as longer saw life, better cutting grades, no bark clogging of machinery, lower handling cost, and a higher percentage of utilized waste. To handle full-size logs, the barking equipment must be large and only a permanent mill could support the necessary investment.

Removal of bark at the sawmill, *after* sawing, reduces the size of equipment required, but this is of advantage only to the small mill. It necessitates more handling of wood and there is a high loss of good wood when the buzz barker method is used.

Barking of slabs at the pulpmill is advantageous, if a regular supply of slabs from several sawmills can be obtained. If trucking is the only form of transportation, it is somewhat cheaper to carry slabs than chips. With chipping under control of the pulp mill, there is more uniformity in cleanliness and chip size.

Conclusions

There is a need in the sawmill industry for bark-removal equipment, so that slabs and edgings can be utilized in the form of pulp chips. Until a cheap, low-powered log-barker becomes available, small saw mills must rely on the use of the buzz barker, and further improvement of this device is indicated to reduce wastage of wood and labor.

The large sawmill (100,000 bd. ft. per day) should bark logs before sawing and, while there are several machines available for this purpose, further improvement is indicated to provide the following qualities:

1. Barking should be on a continuous basis.
2. Barking should be done without rotation of the log to avoid difficulties with crookedness.
3. Mechanical handling should be incorporated to reduce labor costs.
4. Bark should be removed completely without loss of good wood, regardless of season or length of soaking.
5. The machine should use power efficiently. No figures on actual or theoretical power requirements are available, but Figure 12, prepared from information on existing machines, shows that 120 hp. per 100 feet per minute of barking speed is average. The rates on which this curve is based were prepared from published and observed data, modified to a basis of average output and average log diameter. The figures cannot be considered as exact, but there is sufficient consistence to indicate a reasonably accurate average value.

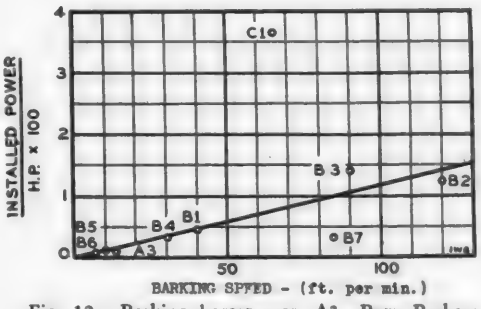

Fig. 12.—Barking horsepower. A3—Buzz Barker; A5—J. and C. Rosser; B1—Thorne Barker; B2—Drum Barker; B3—Waterous Log Barker; B4—Nekoosa Barker; B5—Lowther Post Peeler; B6—Click Post Peeler; B7—Astrom Barker (estimated value); C1—Streambarker.

6. The machine should be as simple as possible to ensure a low first cost and freedom from mechanical troubles. Figure 13 indicates (for 1947) an average first cost of $33,000 per 100 feet per minute of barking speed. Labor cost and maintenance cost have not been included because of insufficient reliable data.

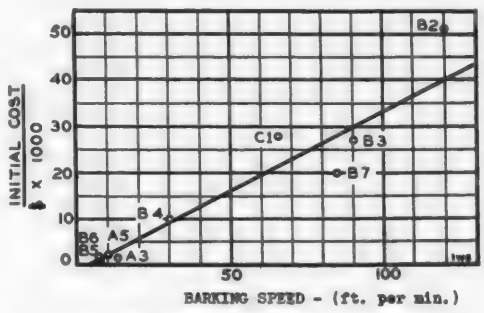

Fig. 13.—Initial barker cost.

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Discussion

Mr. E. W. Fobes (U. S. Forest Products Laboratory): The paper presented by Mr. Smith has been well prepared, and represents considerable work of interest to those concerned with better wood utilization. It is in the nature of an inventory of existing equipment, its capabilities, and limitations.

In reviewing the production data, it is not clear as to the size of the material to which they apply. This is important, especially from the standpoint of length. A 6-inch space between 4-foot bolts being fed to a machine will reduce the net capacity in feet per minute by twice the amount that the same spacing will between 8-foot bolts. This emphasizes point 3 in the conclusions (Mechanical handling).

Since the preparation of Mr. Smith's data, a new barker using an old principle has been announced by the Weyerhaeuser Company. It uses direct pressure as did the willow stripping machines of the 1800's. This raises a question as to the adequacy of the classification used.

There is no difference of opinion as to classification A, the employment of knives. However, a question is raised as to the fundamental difference between classifications B and C. In both cases the action appears to be one of erosion, in one case mechanical and the other hydraulic. Is the erosion the fundamental cause of bark separation or is it a preliminary action?

Bark and wood are bonded together by the cambium layer and therefore it appears necessary to break down that bond to obtain separation. Is this bond broken down by erosion, as indicated by Mr. Smith's classification, or is the final breakdown caused by pressure after erosion removes sufficient bark to make the available pressures effective?

These are some of the points raised by this paper that bring to mind other unanswered questions in need of investigation, so that machines can be built to meet the requirements set forth in the conclusions.

Mr. S. O. Jones (Nelson Electric Manufacturing Company): Mr. Smith has very properly divided mechanical methods of bark removal into two main classes, namely cutter-head methods and abrasion or impact methods. My observation, based on considerable experience in the manufacture and use of bark removal machinery, convinces me that the choice of methods will depend largely upon the type of stock to be processed and the purpose for which the stock is to be used. In the case of pulp wood,

a good impact machine can be very economical, since the purpose is to conserve all of the wood pulp possible. By that I mean to point out the fact that impact machines generally do not remove knots or other protuberances. While this method has its objections for finishing round stock, it is ideally adapted to saving all the pulp possible. However, when finishing poles or fence posts, or processing veneer stock, finish and symmetry are very important and the cutter-head system generally lends itself much better to the job, since unwanted projections are removed and there is no fiber breakage at the surface. Our equipment very successfully finishes poles at a very rapid rate, leaving no hand work to be done at the ends and leaving no objectionable marks or rough surface on the stock.

I will not take the time here to go into the advantages of machine finish poles, since that has been generally acknowledged now by the leaders of the industry and since that subject has been very ably handled in the 1947 proceedings of the American Wood Preservers Association. Having manufactured this machine, I think it is only fair for me to point out that in its present form it is not practical to handle stock less than about 16 feet in length, since it was designed primarily as a pole machine. That still leaves the fence post man and the veneer man sitting on the bank so to speak. Veneer stock requires a machine radically different in design and I regret to say that my machine for this purpose is not yet completed and probably will not be available before the latter part of this year.

Every veneer man knows the high cost of veneer knives and grinding. Consequently, there is urgent need of protecting these knives against foreign matter in the outside of the log. If the log is cleaned and rounded by a cutter head, with less expensive knives, most of the real hazards will be encountered at the time of shaving and the savings in down time and knife grinding will by themselves more than justify the use of special purpose machines to accomplish this cleaning. This is especially noticeable when we consider that a veneer log should be round and smooth at the start of the peeling operation, if for no other reason than to reduce the amount of off-dimension veneer.

Studies on the Chemical Composition of Bark and Its Utilization For Structural Boards*

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Barks from balsam, black spruce, white spruce, eastern hemlock and Douglas fir were analyzed for solvent solubility, ash, "lignin", pentosan, and one percent sodium hydroxide solubility. Experiments were carried out on the alkaline pulping of these barks and on the quantitative determination of the reducing and fermentable sugars present. Preliminary experiments are also reported on the preparation of structural boards of the soft-board and hard-pressed types from eastern and western cedar barks

Introduction

A PROGRAM of research on the analysis of barks from the more important Canadian species was undertaken prior to experimenting on the possibility of utilizing these barks. A previous publication *(1)* dealt with the chemical composition of western red cedar *(Thuja plicata)* bark. The first part of the present paper contains the results of analyses of barks from balsam *(Abies balsamea)*, black spruce *(Picea mariana)*, white spruce *(Picea glauca)*, eastern white hemlock *(Tsuga canadensis)* and Douglas fir *(Pseudotsuga taxifolia)*. The second part of the paper is concerned with a description of the experiments carried out on the preparation of structural boards of the insulation and hardboard types from barks from western red cedar and eastern white cedar *(Thuja occidentalis)*.

Although analyses for certain of the constituents in some of the above-mentioned barks have been reported in the literature *(2, 3, 4)*, comparison of results for different barks is difficult to make. Very often the history of the starting material is unknown or unreported, the solvent extraction of the various barks prior to analysis differs, and methods of analysis may also be different. It was therefore considered advisable to carry out a series of analytical experiments under standardized conditions on materials whose history is well known.

The barks were analyzed by the usual methods applied to wood. These methods are purely arbitrary and the results obtained on barks are perhaps less absolute than those obtained on wood. Nevertheless, the results assist in predicting the behaviour of barks if they were subjected to the technical processing employed in the pulp and paper industry.

History of the Barks and Preparation of Samples

At the Forest Experimental Station at Petawawa, Ontario, ten, 6- to 8-inch diameter black spruce trees from a 70- to 80-year old stand were felled in the spring of the year. Ten trees each of white spruce and balsam, 6- to 8-inches in diameter, but taken from a 50- to 60-year old stand, were also felled. Strips of bark about six inches wide were peeled from the entire length of each tree felled, so that a total of about 75 pounds of bark was obtained from each species. Three pieces of bark about six inches long were cut from each strip of bark (one from the center and one from each end), allowed to air-dry for a week, ground in a Wiley mill using a coarse screen, and placed in stoppered bottles until used. Analyses were carried out about a month after trees were felled.

The Douglas fir bark (2 to 3 inches thick) was obtained from logs which had been towed in salt water and stored at the plant pond of a British Columbia mill until sawn. The bark as obtained was separated into inner and outer fractions with the aid of a knife. Inner bark

* Contribution from the Forest Products Laboratories of Canada, Mines, Forests and Scientific Services Branch, Department of Mines and Resources, Ottawa.

in this instance includes the bark within the innermost layer of periderm. By the method of separation, the outer bark was found to represent 93 percent of the total bark. Samples were ground and stored as described above.

Eastern hemlock bark was obtained from 17-inch diameter trees from a 225-year old stand in Novia Scotia. The bark was separated into inner and outer fractions prior to grinding in the Wiley mill. The outer bark represented 73 percent of the total bark. It might be mentioned that the trees were felled in February of the year, barked in April, and the bark analyzed during the summer months.

Analysis of Barks

Cold- and hot-water solubilities were carried out according to the accepted Schorger procedure (5); ether solubility by extraction with anhydrous ether of two grams of air-dry material in a Soxhlet extractor for eight hours, followed by washing of the residue and drying in an oven at 105 degrees C.; "lignin" by the Standard TAPPI method; one percent sodium hydroxide solubility by TAPPI method T4m–44; and pentosans by tentative TAPPI standard T223m–43. Analyses for "lignin", one percent sodium hydroxide soluble and pentosans were carried out on samples which had been pre-extracted successively in a Soxhlet extractor with alcohol-benzene (1:1) for 24 hours, with alcohol for 24 hours, and with water for 24 hours. All results appear in Table 1. Results of analyses published recently *(1)* on western red cedar bark are also included in this Table.

The water solubilities of balsam, black spruce, white spruce, Douglas fir and eastern hemlock barks are all rather high. The very high figure for white spruce (33.9 percent soluble in cold water) is probably due to the presence of considerable tannin material. Graham and Rose *(3)* report a tannin content for white spruce bark of over 20 percent. It is interesting to note that the Douglas fir outer bark still contains 20 percent of material soluble in cold water, despite the fact that logs from which this bark was obtained were water-towed. Apparently Douglas fir bark in bulk offers considerable resistance to penetration by water. The western red cedar bark also was obtained from logs which were water-transported and the low figure for water solubility is probably caused by the solubilization of materials while the logs were immersed in water *(1)*.

The ether solubilities of all barks except the western red cedar are high, the figure for black spruce being 25.5 percent. Hay and Lewis *(2)* report the ether solubility of black spruce as 14.1 percent while Richter *(6)* reports a figure of 2.26 percent. Such large variations are rather unexpected and may be due to one or more of the following reasons, namely, the age of the tree from which the bark was obtained, the season of the year in which the tree was felled, differences in methods of sampling and analysis of the bark, and natural variation between different trees.

The authors found a pentosan content of 17.4 percent and a "lignin" content of 27.4 percent for black spruce whereas Richter *(6)* reports figures of 8.84 and 45.84 percent, respectively. This difference is probably due largely to the fact that the former investigators carried out their analyses on solvent-extracted material.

It is apparent that the value of results of bark analyses is dependent on a complete

TABLE 1.—ANALYSES ON BARK FROM SIX CANADIAN SPECIES

	Balsam	Black Spruce	White Spruce	Douglas Fir		Eastern Hemlock		Western Red Cedar[b]	
				Inner	Outer	Inner	Outer	Inner	Outer
Cold water soluble (%)	22.6	25.9	33.9	10.3	20.0	22.7	21.8	2.3	1.0
Hot water soluble (%))	26.7	32.3	41.8	13.5	29.7	34.9	30.0	5.3	6.4
Ether soluble (%)	23.6	25.5	22.9	15.7	34.4	17.5	23.9	4.9	6.3
Ash (%)	2.0	2.4	3.1	2.7	0.9	1.5	1.0	2.8	0.9
Successive extractions with alcohol–bensene, alcohol and hot water (soluble %)	36.2	39.7	47.7	16.6	42.9	34.1	40.2	9.3	11.5
"Lignin" (Insoluble in 72 percent sulphuric acid) (%)[a]	32.3	27.4	27.3	41.5	33.3	25.9	52.7	34.3	41.5
Ash in "lignin" (%)	0.2	0.5	1.0	0.3	trace	0.4	trace	----	----
1 percent sodium hydroxide solbule (%)[a]	35.3	39.2	44.0	29.2	44.5	24.1	32.7	20.1	33.6
Pentosans (%)[a]	12.5	17.4	18.3	9.5	7.4	10.7	8.4	10.9	10.3

[a]Analyses for "lignin", one percent sodium hydroxide soluble and pentosans were carried out on material which had been extracted successively with alcohol–bensene, alcohol and hot water. Yields for these three analyses are based on moisture-free extracted bark.
[b]Figures for western red cedar are taken from a report previously published (1).

knowledge of the history of the raw material. Otherwise comparisons and evaluations are impossible to make.

Pulping Experiments

Twenty-gram samples of solvent-extracted balsam, black spruce and white spruce barks, and samples of eastern hemlock and Douglas fir outer barks were heated in a stainless steel autoclave with 300 ml. of five percent sodium hydroxide solution at 170 degrees C. for one hour. The pulp residues from the cooks were filtered and washed with hot water, dried, weighed, and analyzed for "lignin" and pentosans.

The filtrate from each cook was acidified, and the floccultent ligneous precipitate formed was centrifuged, washed on the centrifuge with water several times, dried in a vacuum oven, weighed, and analyzed for methoxyl and pentosans. The results of these experiments appear in Table 2. Results previously obtained on western red cedar bark *(1)* are also included in this Table.

It may be noted that, notwithstanding the relatively mild cook used, the yields of pulp are mainly in the 30 percent range. The yield from Douglas fir is a little lower, being 24.9 percent, while the yield from balsam is a little higher, being 39.5 percent. The "lignin" contents of the pulps range from 5.7 to 19.6 percent.

A second series of cooks was made in which the five samples of bark were cooked under more drastic conditions, *i.e.*, ten percent sodium hydroxide solution at 170 degrees C. for four hours. The results of these experiments are given in Table 3. The yields of pulp obtained are very low, ranging from 7 to 17 percent, but the "lignin" contents are considerably higher than in the pulps obtained under milder conditions. Severe alkaline pulping conditions apparently solubilize a much greater proportion of the non-ligneous components, presumably carbohydrates, with but little greater removal of ligneous constituents. Resistance to the pulping action of alkaline solutions by portions of the "lignin" fraction of barks has been reported in the literature on a number of occasions *(7, 8)*.

The methoxyl contents (see Table 2) of the "lignins" in the spent liquors from the five percent sodium hydroxide cooks are much lower than those of wood, ranging from 4.8 to 8.8 percent.

In general, the results of the pulping experiments fit into the pattern of expected chemical behaviour of barks.

Fermentable Sugars in the Barks

The amount of fermentable sugar present was determined for the five solvent-extracted bark samples used in the pulping experiments and the five pulps obtained by cooking these extracted barks with five percent sodium hydroxide solution at 170 degrees C. for one hour. The barks were hydrolyzed with sulphuric acid according to the method of Saeman, Bubl and Harris *(9)*. The hydrolyzates were analyzed for reducing sugars by the Shaffer and Somogyi method *(10)* and for sugar fermentable with baker's yeast by the rapid yeast sorption method

TABLE 2.—PULPING EXPERIMENTS WITH FIVE PERCENT SODIUM HYDROXIDE SOLUTION

Extracted Bark	Lignin in Extracted Bark (%)	Pulp Yield (%)	Lignin in Pulp (%)	Pentosans in Pulp (%)	Lignin in Spent Liquor: Yield on extd. bark basis (%)	Lignin in Spent Liquor: Methoxyl in Lignin (%)	Lignin in Spent Liquor: Pentosans in Lignin (%)
Balsam	32.3	39.5	15.1	5.1	18.6	8.8	2.9
Black spruce	27.4	33.7	8.9	6.9	18.7	7.3	4.1
White spruce	27.3	30.3	5.7	5.3	18.7	4.8	2.9
Eastern hemlock outer bark	52.7	31.6	19.6	4.7	32.1	7.9	1.9
Douglas fir outer bark	55.5	24.9	7.6	5.6	37.0	7.5	1.2
Western red cedar outer bark(a)	41.5	33.6	12.1	6.7	39.2	5.0	1.7

(a)This sample was pulped with five percent sodium hydroxide solution at 170 degrees C. for 4 hours.

TABLE 3.—PULPING EXPERIMENTS WITH TEN PERCENT SODIUM HYDROXIDE SOLUTION

Extracted Bark	Pulp Yield (%)	Lignin in Pulp (%)	Pentosans in Pulp (%)
Balsam	10.3	19.1	1.3
Black spruce	16.6	18.4	5.3
White spruce	17.2	19.0	2.3
Hemlock—Outer bark	13.2	35.4	4.5
Douglas fir—Outer bark	7.3	12.7	1.6

(11). Reducing sugars were calculated as glucose. Results appear in Table 4.

It may be noted that the amount of fermentable sugar present in the solvent-extracted bark samples ranges from 32.0 to 47.3 percent. However, when calculated on the unextracted bark basis, the fermentable sugar range is only from 18.3 to 30.1 percent.

The figures for the fermentable sugars present in the pulps, calculated on the unextracted bark basis, are of interest, ranging from only 13.7 to 21.4 percent. Assuming that these fermentable sugars originate from a cellulosic type of polysaccharide, it is apparent that the amount of cellulosic material in the unextracted bark is quite small. The amount of cellulose, if present, would probably be considerably less than in the 13.7 to 21.4 percent range, as these figures also include sugars which originate from hemicellulose material present.

TABLE 4.—ANALYSES FOR REDUCING AND FERMENTABLE SUGARS

		Balsam	Black Spruce	White Spruce	Eastern Hemlock Outer Bark	Douglas Fir Outer Bark
Extracted Bark	R.S.(a) (%)	61.3	61.6	57.5	43.4	41.2
	F.S.(b) (%)	47.3	43.4	39.7	33.8	32.0
	F.S. Calculated on unextracted bark basis (%)	30.1	26.6	20.8	20.3	18.3
Pulp from Extracted Bark	R.S. (%)	91.5	99.1	99.6	85.9	103.0(c)
	F.S. (%)	85.0	91.0	92.5	79.7	96.7
	F.S. Calculated on unextracted bark basis (%)	21.4	18.8	14.6	15.1	13.7

(a) R.S. represents total reducing sugars calculated as glucose.
(b) F.S. represents fermentable sugars.
(c) In reporting of results, the possibility exists of obtaining over 100 percent of the weight of the sample as glucose, because in the conversion of the polysaccharides to monosaccharides during acid hydrolysis water is taken up and this water is included in the weight of the reducing material present.

Structural Boards from Eastern and Western Cedar Barks

Because of the fibrous nature of eastern and western cedar barks, it was considered possible that these materials could be used in producing structural boards of reasonably good strength. As a result, experiments of a preliminary nature were undertaken on the preparation of boards of both the insulation and hardboard types from these raw materials.

Softboards

The material used consisted of either eastern cedar bark chips about one-inch square or western cedar bark slabs which had been put through a two-knife laboratory chipper. The material was steamed at 100 p.s.i. for 20 minutes and then treated at 2.5 percent consistency in a Valley beater for 13 minutes in the case of the eastern cedar and for 20 minutes in the case of the western cedar bark. Three percent of a mixture of rosin and wax emulsion size was added to the stock in the beater prior to the formation of sheets or mats on a 12 by 12 inch hand-sheet machine. The mats were then formed into boards by hydraulic pressing between wire screens at 100 p.s.i. for one minute. Boards were also made in which the mats were pressed to a thickness of 0.45 inch in the press. After removal from the press, such boards increased in thickness to close to 0.5 inch. The boards were dried in an oven at 125 to 140 degrees C. for six hours and allowed to condition for a week at 65 percent relative humidity and 22 degrees C.

Three boards were made from bark alone and three boards from mixtures of bark and (1) ten percent sulphite pulp screenings and (2) ten percent groundwood pulp screenings. From each set of three boards, four to eight strips, 10 inches long and 1.5 inches wide, were tested for tensile strength, and four pieces, 4 by 4 inches in size, were tested for water absorption in two hours. The average results appear in Table 5.

It was aimed to prepare boards about 0.5 inches thick and of a specific gravity of about 0.28. It was considered that the boards would be acceptable as regards tensile strength, if they conformed with U. S. Federal Specification LLL-F-321b December 17, 1942, for fibreboard, which calls for a minimum tensile strength of 150 p.s.i. The water resistance aimed for was a maximum absorption of water

TABLE 5.—PROPERTIES OF SOFTBOARDS FROM EASTERN AND WESTERN CEDAR BARKS

Material	Eastern Cedar		Western Cedar	Western Cedar and 10% Sulphite Screenings	Western Cedar and 10% Groundwood Screenings
Pressing conditions	100 p.s.i.	Pressed(a) to desired thickness	100 p.s.i.	100 p.s.i.	100 p.s.i.
Thickness (inches)	0.37	0.48	0.46	0.45	0.52
Specific Gravity	0.38	0.29	0.27	0.28	0.30
Tensile Strength (p.s.i.)	617	409	42	210	93
Water Absorption in 2 hours (% by volume)	6.1	11.4	3.6	7.4	5.8

(a)Pressed to a thickness of 0.45 inch in the press.

of seven percent upon immersion in water for two hours.

It may be noted from the Table that boards from eastern cedar, when pressed to 100 p.s.i., have high tensile strength (617 p.s.i.) but are too thin and too dense. When pressed to a thickness of 0.45 inch in the press, the tensile strength, though a little lower (409 p.s.i.), was still considerably above the minimum requirements for softboards. Western cedar bark alone does not produce a satisfactory board with regard to tensile strength but does come within the acceptable range when ten percent of sulphite pulp screenings are added.

The water resistance of most of the boards was fairly good. It is considered that this property can be controlled, within limits, by proper sizing.

It might be pointed out that the experimental work reported here is only of an exploratory nature. The conditions used as regards presteaming, method of fiberizing, sheet formation, and pressing are by no means optimum. The results are reported merely to indicate that a good possibility exists of producing softboards of the insulation type from eastern and western cedar barks. It is intended to extend this investigation to include other barks and to carry out a more comprehensive investigation, using an attrition mill instead of the Valley beater.

Hardboards

Boards about 0.17 inches thick and of a specific gravity of about 0.9 were prepared. The procedure for their preparation, upto the stage of pressing, was the same as that described for the softboards. At this point the mats were placed in a mold with a wire screen at the bottom and a stainless steel plate, coated with a lubricant, at the top. They were then pressed at a maximum pressure of 500 p.s.i. and a maximum temperature of 190 degrees C. for ten minutes, according to the three-stage procedure recommended by Schwartz, Pew and Schafer *(12)* for the preparation of hardboards from wood waste. The boards were allowed to stand at 65 percent relative humidity and 22 degrees C. for about a week prior to testing.

Boards were made as before from bark alone and also from mixtures of bark with (1) ten percent sulphite pulp screenings and (2) ten percent groundwood pulp screenings. The methods of testing were the same as for the softboards, except that specimens were also tested for static bending on a span of three inches. The average modulus of rupture as well as the average results of other tests are given in Table 6. Also included in this Table are the results on a commercial hard-pressed fibreboard.

Figures for modulus of rupture and tensile strength on eastern cedar are about double the corresponding figures on western cedar. However, they are still considerably lower than the strength figures for a commercial hard-pressed fibreboard, even after the addition to the stock of either ten percent sulphite pulp or groundwood pulp screenings. They are also considerably below the minimum requirements specified in U. S. Federal Specification LLL-F-311 for hard-pressed fibreboard. These specifications call for a minimum density of 60 lb. per cu. ft.

TABLE 6.—PROPERTIES OF HARDBOARDS FROM EASTERN AND WESTERN CEDAR BARKS

Material	Eastern Cedar	Eastern Cedar and 10% sulphite screenings	Eastern Cedar and 10% groundwood screenings	Western Cedar	Western Cedar and 10% sulphite screenings	A commercial hardboard
Thickness (inches)	0.17	0.17	0.18	0.19	0.20	0.14
Specific Gravity	0.86	0.91	0.92	0.90	0.90	1.06
Modulus of Rupture (p.s.i.)	2790	3020	----	1530	1770	6660
Tensile strength (p.s.i.)	1992	2987	2612	1100	1167	4460
Water absorption in 2 hours (% by volume)	5.2	11.1	5.6	12.0	----	8.0

and a minimum modulus of rupture of 6000 p.s.i. for boards 0.125 ± 0.0156 inches thick. It is possible, however, that the properties of the boards might be improved to a certain extent by improvements in methods of preparation.

Conclusions

From the experiments carried out, although limited in scope, there are indications that a softboard of the insulation type, of acceptable tensile strength, can be prepared from eastern cedar bark. Western cedar bark alone produces a board of very low tensile strength. The strength of this board is, however, increased considerably by the addition of ten percent of sulphite pulp screenings to the stock.

Hard-pressed boards prepared from eastern cedar bark are considerably higher in modulus of rupture and tensile stength than boards from western cedar bark. However, the properties are still considerably below the present requirements specified for commercial boards of this type.

Acknowledgments

The authors wish to thank Dr. F. Bender and Mr. G. Latremouille of the Forest Products Laboratories for cooperation in the planning and the carrying out of the experiments on the preparation of structural boards. Thanks are also extended to the Division of Timber Mechanics for carrying out the physical tests reported on these boards.

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Discussion

Dr. Harry F. Lewis (The Institute of Paper Chemistry): The authors of this paper list analytical data estimated on bark by the methods developed for the analysis of wood. These are largely empirical methods developed for wood; they may be misleading when applied to bark, as the authors themselves indicate.

One of the worst offenders is the so-called "lignin" determination. The method defines as lignin the quantity of material remaining insoluble after treatment with 72 percent sulfuric acid and further hydrolysis with 3 percent acid. There is some reason for believing that this is the case with extracted wood, but it certanly is far from the case with bark. One class of bark components appearing as lignin in this test is that of a group of compounds somewhat like the "humic acids," in that they are complex phenolic acids. This material makes up better than half of the "lignin" estimated to be in redwood bark.

Fundamental work is needed to identify bark constituents and to develop more satisfactary methods for estimating the important constituents at least by classes.

TECHNICAL SESSION IV

Tuesday, March 23, 1948, 10:30 A. M.

Open Forum: Coordination of Research in the Field of Forest Products

Moderator: Carl A. Rishell, Director of Research, National Lumber Manufacturers' Association, Washington, D. C. *(Southeast Regional Board Member, FPRS)*

Recorder: Robert A. Cockrell, Associate Professor of Forestry, University of California, Berkeley, California. *(Southwest Regional Board Member, FPRS)*

Discussion Leaders:

Armin Elmendorf, President, The Elmendorf Corporation, Chicago, Illinois

L. J. Markwardt, Assistant Director, U. S. Forest Products Laboratory, Madison, Wisconsin

Irving H. Isenberg, Research Associate, The Institute of Paper Chemistry, Appleton, Wisconsin

Frank H. Kaufert, Chief, Division of Forestry, University of Minnesota, St. Paul, Minnesota

General Discussion—*see p. 147*

Opening Remarks

Carl A. Rishell

Director of Research, National Lumber Manufacturers Association, Washington, D. C.

AS MODERATOR for this forum, I have been allowed exactly five minutes to tell you what it is about and what we expect may be accomplished by the forum, and to state the procedure which will be followed.

Since this is a discussion of Research Coordination, I will first attempt a definition of our subject, with which each of you is, of course, entitled to agree or disagree:

> "Coordination of research is the act of bringing research organizations into such cooperative effort that unnecessary duplication will be avoided."

Whether this can best be brought about by voluntary cooperation or through legislated compulsion may be a matter of interest to this group and should be discussed. In any event, it is my opinion that we can spend our few research dollars to best effect when reasonable coordination is obtained.

The principal feature of this forum will be the presentation of four papers on the subject, as follows:

As a representative of private industry, Mr. Elmendorf will present his ideas regarding the objectives for all forest products research and will tell you how he believes coordination will help us to work towards these objectives.

Mr. Markwardt will outline, in brief of course, the past history of efforts in research coordination and, I presume, will provide us with his views as to how coordination can be achieved.

Mr. Isenberg will tell us what the pulp and paper industry is doing to obtain research coordination and I hope he will tell us whether he thinks this can be used as a pattern for the over-all industry.

Mr. Kaufert has been chosen to provide us with his plan whereby the Forest Products Research Society can achieve reasonable coordination.

At the conclusion of these presentations there will be opportunity for you to question or comment on any statements made by the four speakers. In doing so, please bear in mind that these speakers have intentionally injected controversial statements into their talks for the purpose of inviting just such criticism as I hope you will make.

Now, before turning this meeting over to the speakers, it is my desire as a member of this Society to ask the president to appoint the strongest possible standing committee, whose function will be to lead this Society in the effective promotion of research coordination in the field of wood products.

Forest Products Research in Industry Laboratories

Armin Elmendorf
President, The Elmendorf Corporation, Chicago, Ill.

LABORATORIES conducting research in the field of forest products may be classified in two groups, those financed by industry itself and those depending upon public funds for their support. In the former group belong laboratories maintained by manufacturers, private laboratories conducting research under contract for manufacturers, and industry association laboratories. In the latter group belong the laboratories supported with state and federal funds. It is of course to be expected that the activities of the various laboratories will overlap and that research efforts are frequently duplicated. Is this desirable, or would the forest products industries fare better under more segregation and specialization of research efforts? Should the Forest Products Research Society foster efforts at better coordination and, if so, can a plan to that effect be drawn up?

When differences of opinion exist regarding the best means for achieving a common goal, the areas of agreement must first be sought and stated, if concerted progress toward that goal is to be achieved. In connection with the problem of research coordination, is it not substantially correct to say that the purpose of all research in the field of forest products is the creation of a fund of scientific and technological knowledge in such a manner and by such agencies that it will be most readily applied in industry? Even purely theoretical or fundamental knowledge must eventually, or perhaps indirectly, influence the work of some engineer or technologist in order to justify its cost. In forest products research the luxury of knowledge for knowledge's sake can not exist. May we not also assume that there is substantial unanimity in acceptance of the principle that when public funds are employed this is done only because it is believed that private industry is thereby helped, in particular those segments of industry not financially able to conduct research work? Do we not also all agree that the possibility of making a good profit must exist if industry is to take the financial risk of commercializing successful laboratory work? Due to the many unknown factors that unexpectedly arise and confront the manufacturer of a new product, factors that cause frustration and much discouragement, and that frequently result in heavy losses that were not anticipated, the possible profit, after taxes, must be greater, then, than the normal profits of business enterprise. The pioneer must be rewarded if we are to have any more pioneers.

Every major country recognizes the need for granting patents to inventors in order to encourage them. Society has found it advantageous to give inventors a temporary monopoly to the benefits of their inventions, because invention creates prosperity and a higher standard of living. It is, however, not the act of inventing that raises the standard of living of a community but the process of making the invention available. Invention without manufacture and distribution would be futile. While success in research and invention involves financial risk, success in manufacture and merchandising usually involves much greater risk. Society encourages the inventor with patents in the hope that he will become a manufacturer. Discouragement to the manufacturer to take the risk of pioneering is a discouragement to the inventor. It is the manufacturer who must be temporarily protected from competitors who have not assumed his risk. In a free enterprise society, it is against this background that we must view the contributions and activities of research agencies.

In the appeals made to appropriation committees by those who are seeking public funds, we generally find statements to the effect that the industry of the state or the region would be helped through the generous support of the laboratory. I wish to show that while this is generally the case, the exact opposite may also

develop and that industry may be handicapped and deterred by certain types of research activities in publicly supported laboratories.

We must always remember that the road to reimbursement for the very substantial risks a pioneer manufacturer takes is a very uncertain and tortuous path. Great care should therefore be exercised by the management of publicly supported research laboratories to see that they do not make the work of the manufacturer even more difficult than it normally is.

I believe that most of the work being carried on today in laboratories maintained with federal and state funds should be and is being welcomed by manufacturers as useful. In this category belong the data on the physical properties of the various species of wood and how these properties vary with moisture, density and place of growth; information on the properties of adhesives and methods of testing adhesive bonds; studies on decay and its control; methods of seasoning wood; reports on means for bending, sawing and planing wood. The list could be increased to great length and numerous problems not yet under investigation might be added. Such information is valuable, and due to the fact that it is of enduring importance to many people its acquisition is appropriately financed with public funds.

It will be noted that there are some common denominators to the subjects listed. They deal with the acquisition by test, compilation and analysis of data describing various forest products and their behavior. Whenever manufactured products are tested, their origin is hidden in a code, and most manufacturers whose products are tested, should approve the investigation. The tests are generally eminently fair and objective and can assist the manufacturer in improving his product.

In the end it is the taxpayer who provided the funds for such investigations and who benefits in the superior products that ensue.

We might say, therefore, that fundamental research, the testing of all products of the forest, the testing of manufactured products, the study of the properties of wood and its derivatives, the compilation of statistical data relative to forest products and the giving of free advice on the application of such knowledge to manufacturers' problems are all logical activities of laboratories financed with public funds. It would be unsound for any manufacturers to engage in such activities on any extensive scale.

On the other hand, it is in my opinion unsound for a publicly financed laboratory to engage in the development of new products or processes which might be subject to patent protection and which require the collaboration of industry to bring them into use. I can say without reservation that no manufacturer will engage in a research program aimed at the development of new products, if he is aware of the fact that some government or state laboratory is likewise at work upon the same problem, for by doing so he may some day find himself confronted with a serious patent priority entanglement. If, as a consequence, he abandons his research to the publicly financed institution and patents are obtained by the latter, he will then also be very reluctant to finance the further development of the project beyond the laboratory stage. As previously stated, the risks in manufacturing and commercializing a new product or process are so great that a manufacturer cannot afford to take them unless he is assured the protection of some kind of a temporary monopoly. A patent issued to a government agency cannot be a true patent because licenses must be granted to all who are qualified to use them, and no exclusive license can be permitted. The net result is that private research has been discouraged, and the development of inventions through the pilot stage to commercial production has been made practically impossible. Industry loses out and so does the public, and even the small satisfaction of seeing the results of his work reach fruition in industry is denied the research worker.

It is sometimes contended that, in the interest of the small manufacturer, pilot operations should be set up with public funds. Here also the argument falls because no protection is provided the manufacturer against the largest risk of all, that of introducing the product to the buying public and building up consumer demand for it. No manufacturer will willingly pay the great cost of pioneering and publicizing a product, if by doing so he merely paves the way for his competitors. If he finances the pilot plant himself, he always has a chance for some patent protection, and in any event he can keep

the operation secret for a while so that, hazardous as it may be, he does get a kind of temporary protection.

In my opinion, therefore, research leading to patentabl products or processes, and the financing of experimental manufacture should be left entirely to private industry. Only when this is done, can or will the results of the laboratory pass successively from the laboratory through semi-commercial manufacture to eventual commercial production. Publicly financed research can be of increasing help to industry, but if such research is aimed at the development of new and patentable products or processes it may seriously deter industrial progress.

In conclusion, I would like to suggest that a committee be appointed by this Society with instructions to draft a set of recommendations outlining fields of activity which might serve as a guide to the management of the various types of laboratory in setting up their agenda, so that the maximum public benefit may be derived from the great amount of research work in the field of forest products that lies ahead of us. I would also suggest that in their report to the Society this committee submit an ample list of specific projects which in their opinion lend themselves to the respective type of laboratory and, further, that this committee report to the Society at its next annual meeting.

Coordination of Research in the Pulp and Paper Industry

Irving H. Isenberg

Research Associate, The Institute of Paper Chemistry, Appleton, Wisconsin

THERE are many illustrations of coordination of research in the pulp and paper industry. First of all, we might point out that there are two large groups which include nearly all, if not all, of the manufacturers of pulp, paper or paperboard in the United States —the American Paper and Pulp Association and the National Paperboard Association.

The American Paper and Pulp Association might be termed a federation of the many divisions of various manufacturers. The Association has a technical committee whose aim is to program, administer and review all Association activities in technical and affiliated fields. There are five subcommittees to assist it. Two of these, the committee on coordination of research and the committee on conservation of materials, might be termed coordinating, while the remaining three, biological control, classification and definitions, and instrumentation research, are exploratory and research groups. Membership on these committees is limited to persons in the employ of companies associated with A. P. P. A.

The purposes of the various subcommittees are as follows:

1. Biological control—to study sanitary standards and the use requirements of paper in respect to bacteriological conditions.

2. Classifications and definitions—to classify and define all kinds of paper, paperboard, pulp and allied products and to define papermaking terms.

3. Conservation of materials—to collect information on wastes encountered in manufacture from cutting the wood to the finishing room.

4. Coordination of research—to maintain a current list of research projects that are under way at public institutions, universities and other research agencies and to make recommendations as to these agencies in respect to their research programs, principally for the purpose of avoiding duplication and overlapping of effort.

5. Instrumentation research—to examine critically and to evaluate the utility of all existing instruments and techniques designed for the purpose of determining the physical and chemical properties of paper; to develop new testing instruments and techniques where none are now available; and to conduct concurrently fundamental studies of the properties of paper.

In the last case it might be stated that, since 1934, 69 reports have been issued, covering 30 properties of paper and 67 instruments.

In addition to these committees from the federated body, many of the divisions have their own technical committees. For example, the Writing Paper Manufacturers Association is studying fibrous raw materials sources and the Glassine and Greaseproof group study sanitary problems in packaging.

The National Paperboard Association which is constituted directly by individual companies has a technical committee. One of their projects is biological research at Syracuse University.

There are several other organizations national in scope which must be discussed.

The American Pulpwood Association has several engineers who devote considerable time to cooperation with logging equipment industries, as well as to the direct needs of their membership.

The Technical Association of the Pulp and Paper Industry (known as TAPPI) has many standing committees, some of which work on standardization of methods and others on cooperation of research. The fundamental research committee has sponsored symposia on various occasions. Of special interest are those on pulpwood in Detroit in 1946, chemical components

of wood at Appleton in 1947, and that on physical properties planned for Madison next August. Monographs on the first two have already appeared. Other committees to mention as examples are alkaline pulping and engineering. The excellent bibliographies edited by C. J. West certainly contribute to the prosecution of research.

The National Council for Stream Improvement (of the Pulp, Paper and Paperboard Industries, Inc.) is an autonomous body founded in 1943. It embraces all types of mills. Its objectives include (1) solution to stream improvement and waste utilizatiton of industry through research, cooperation with universities and other institutions, government agencies and scientific organizations both of a national and international character, (2) collection and dissemination of information to members, (3) advising individual members on problems, and (4) presentation of common viewpoint in connection with existing, pending or proposed local, state or federal legislation and regulations.

The Council sponsored a fellowship at the Mellon Institute beginning in 1944. There are also at present specific phases of the over-all problem being studied at Purdue, Rutgers, Michigan, Kalamazoo College, the Institute of Paper Chemistry, Manhattan College, Virginia Polytechnic Institute, Louisiana State University, Oregon State College, and Syracuse.

In 1929, an adventure in education and research for a specific industry began when The Institute of Paper Chemistry was founded at Appleton. At present 100 companies support this nonprofit organization, Broadly speaking, research at The Institute of Paper Chemistry may be classified under three headings:

1. Student research in partial fulfilment of the requirements for the Ph. D. degree. The results are available to all members.

2. Institutional research, initiated by staff members and financed by general funds.

3. Cooperative research, wherein the Institute contracts to work for a member or an allied industry on a confidential problem; sometimes sponsored by groups or segments of the industry. Presently prominent in the latter class are the instrumentation, biological control and stream improvement program previously mentioned and utilization of sulfite waste liquor and container research.

Naturally, a library is a very important adjunct to the educational and research pursuits of the Institute. There are at present 13,000 bound volumes, 250 periodicals subscribed to, and a file of patents pertaining to the industry on hand. Library Notes, including abstracts to articles and patents, are published monthly. These are sent to all members and are also open to subscription.

Several groups which sponsor research in the Container Laboratory at The Institute of Paper Chemistry are the Fourdrinier Kraft Board Institute, the Shipping Container Institute, and the Jute Research Group.

An excellent example of more localized coordination is the Sulfite Pulp Manufacturers Research League of 11 Wisconsin companies and one Michigan company. This group has sponsored research on utilization of sulfite waste liquor for several years. One of the results of this research is the construction of a plant at Rhinelander by the Lake States Yeast Corporation to produce *Torula* yeast.

Another local group, the Kraft Committee on Waste Disposal in Wisconsin, has now been integrated into the National Council on Stream Improvement.

Thus the industry is cooperating in a concerted effort to solve some of its common problems.

How does research in the paper industry elate to the over-all picture? It would seem that any advance which it makes in closer utilization is a step in that direction. Another very important point is that often it is a question of economics before we can put technical solution into operation. More coordination of effort is needed in this area.

Our country does have several integrated wood-using industries, but many more are necessary.

A Plan For Coordination of Research

Frank H. Kaufert

Chief, Division of Forestry, University of Minnesota, St. Paul, Minnesota

I HAVE been asked to formulate an over-all plan which might lead to a reasonable degree of coordination of forest products research among the agencies and interests represented in the Forest Products Research Society, as well as those groups working in or interested in forest products research and as yet not represented in our membership.

The desirability and need for such coordination has been adequately emphasized by the previous speakers on this panel. Actually, they have done somewhat more than break the ground or develop the basis for my presentation; in fact, they have pretty well covered some of the points I had planned to make. Also, in this introduction I would like to point out that this plan may be something like UNO, something idealistic and worth striving for but not readily achieved. Progress is certain to be slow and any success that is achieved will definitely be through cooperative effort and not through any attempt to legislate, divide, or dictate.

The previous speakers have pointed out that the very organization of the Forest Products Research Society is a long step in the direction of coordination—a step so significant that many of the additions and refinements we may propose are relatively insignificant.

I am certain that through the two meetings we have held we have achieved a certain degree of coordination of research among the agencies represented. Through future meetings, both national and sectional or regional, we are certain to get additional coordination. However, a great deal could be accomplished in coordinating and advancing research in forest products, particularly on a regional or local basis, by arranging or participating in joint meetings with regional or local groups of the American Chemical Society, Society of American Foresters, Agricultural Engineering Society, etc. Such joint meetings would aid in focusing attention on the work of our group and could bring us new members, in addition to aiding in coordinating the work of some very diverse groups interested in often unrelated phases of forest products research.

Secondly, rating high in our plans for the future and an effective means of coordinating research effort, should be the rapid initiation and expansion of our abstracting program. It does not appear to be an unreasonable objective to consider an abstracting service for the future that would cover the entire field of forest products research and which would make available on an annual or monthly basis summaries of all forest products research in the U. S., Canada, and other countries.

My third proposal relates to the publication, at intervals, of lists of research projects being carried on by individuals and agencies represented in our Society, as well by groups not now represented. The National Lumber Manufacturers Association has made an excellent start on this type of project, which could well become an important function of the Society. The magnitude of such an undertaking is fully appreciated, but it appears to be an essential step in the education, or dissemination-of-information, process necessary to cooperative coordination, which is certainly the only type of coordination we can hope to achieve.

Fourth, as we grow, we will need a service bureau. The successful functioning of service bureaus in other strong societies an their importance in these organizations indicates that we cannot expect to grow in numbers and strength unless we provide the type of aid to members that can be furnished through service bureaus.

Fifth, the Society should consider the periodic preparation by individuals or committees of monographs on specific subjects. Stimulation of research and the increased numbers of papers, even though they are abstracted, does not simplify the task of literature reviews

Monographs prepared by competent individuals, on the other hand, would help collect and summarize information on specific subjects and would be a valuable aid in providing background for new projects and in preventing repetition. Next to the abstracting service, the preparation of such monographs could well result in more forest products research coordination than any other single effort we might make.

My sixth and last point may be somewhat off the reservation, but I feel that we need to take some part in sponsoring or encouraging fundamental research. We need to provide a place on our program for the presentation of basic or fundamental research projects. Granted that it often is easier—and more interesting—to listen to the presentation of applied research reports, we still should not overlook the fact that lack of basic information on the material we are working with may prove the greatest impediment to progress in improving and increasing the use of forest products. We should consider the presentation of basic or fundamental research papers on subjects of interest to the Society, such papers to be prepared by outstanding authorities who may or may not be members of FPRS.

Coordination of Research in the Field of Forest Products

L. J. Markwardt

Assistant Director, Forest Products Laboratory,[1] Forest Service, U. S. Department of Agriculture

I HAVE been asked to describe briefly the history of past efforts that have contributed to the coordination of research in forest products, and to indicate what I think the Society can do to further this objective.

Since our English language frequently lends itself to misunderstandings, I should like to clarify my interpretation of the subject. In the first place, we presumably should not be handicapped in this discussion by any limitations implied in the dictionary conception of the verb "coordinate," meaning "to regulate and combine in harmonious action." I prefer rather to think of the need as one of cooperation in forest products research: "the association of a number of persons for their common benefit and collective action in pursuit of common well being." Here is a field in which the Forest Products Research Society can be of invaluable service.

I have the conviction, shared by others, that there does not seem to be any hope or need of "regulating" or directly "controlling" forest products research that is to be undertaken by various organizations, except that financial agencies will naturally maintain some kind of control over the research they pay for. Hence, any group or committee that does not have financial control can do no more than "influence" or "persuade." It cannot "coordinate" in the sense of "regulating," but more significantly it can work toward the same objective by promoting "cooperation" in research.

Also, it must not be overlooked that there has been and will be conducted considerable restricted or confidential industrial research, which has as its primary objective the benefit of the company or organization that sponsors the work. Such work may not only be not subject to "influence" and "persuasion," but also may not even be reported.

Furthermore, there does not appear to be any possibility of partitioning or dividing research into compartments designed to prevent all overlapping and duplication, or of authorizing the many research agencies to stake out individual claims to some specific field of research, whether fundamental or applied. I believe that there is justification, under well-considered circumstances, for some duplication of research, particularly if it brings to bear a different approach on a difficult fundamental problem. Associated with this thought is the continuous need in applied research of adapting the results of basic findings to the varying conditions and diverse species in different regions of the country. Research problems generally cannot be isolated like individual paving blocks, but rather tend to overlap like shingles.

The challenging thought with respect to forest products research is that there is an unlimited amount of work ahead that can constructively engage the talents of all available organizations for an indefinite period of time. It remains for each agency, *in the light of what is being done and has been done elsewhere,* to carry on the work for which it is best qualified, and for which there is greatest need.

Now that we have examined some of the limitations and qualifications relating to "coordination" of research, let us examine constructively what has been and can be done on "coordination" through cooperation.

The need for cooperation in forest products research obviously grows with the increased interest and activity in this work, and with the increased number of agencies conducting or sponsoring research.

[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

Up to the present time, I do not know of any organization that has attempted or has been strategically fitted to promote or correlate cooperation in forest products research, although certain activities have contributed to this end. For example, committees of the National Lumber Manufacturers Association have from time to time met at the Forest Products Laboratory to discuss research progress and research problems. Much good has come from such conferences, and they have had an influence on the specific problems and trends in the research program.

Another significant but radically different approach toward cooperation in research is the compilation and publication by the Research and Development Committee of American Forest Products Industries of "A Bibliography of Fundamental and Applied Research in Forest Products." The purpose of this publication is to summarize and classify, and to show the source of (1) reliable scientific knowledge and technical information available as a result of fundamental and applied research in forest products by research agencies, including educational institutions, and private laboratories if not confidential; and (2) the further research needed to round out more completely the knowledge on wood needed for maximum wood products development. This bibliography, when currently kept up-to-date, can serve a very useful and valuable function.

A still different means of promoting cooperation is through the publication of research findings, or more specifically through the publication of a comprehensive abstract covering the field of forest products research and development. Perhaps the best known of present abstract journals is "Chemical Abstracts," but as the name implies this is not concerned specifically with forest products, and, furthermore, the abstracts are regarded by some as far too brief.

Less well known in the United States, but representing an excellent type of informative abstract service, is the publication "Forestry Abstracts," issued quarterly by the Imperial Forestry Bureau, Oxford. Although devoted principally to Forestry, one of the ten chapters of the abstract section is entitled "Forest Technology; Forest Utilization." This journal gives excellent coverage in its field, and might well be used as an example in considering the needs in the field of forest products.

It was a conception of the great need for and possibilities of closer cooperation in forest products research that led to the conference on State and Federal Forest Products Research Programs at Madison, Wisconsin on March 18–20, 1946. This meeting in perspective was an historic event, for out of it stemmed the formation of the Forest Products Research Society.

I have mentioned that the key to coordination is the formation of research programs *in the light of what is being done and has been done elsewhere.* This leads logically to the conclusion that the best opportunity for cooperation in the broad sense of influencing research programs is through the medium of the Forest Products Research Society. This Society can be the fountainhead of information on *what is being done and has been done elsewhere.* Its broad function is to provide a medium for (1) disseminating information on all research projects and programs currently under way, wherever they may be, and (2) publicizing research findings, at least in abstract form. The consummation of such an objective would provide an easy means for anyone to determine systematically what research work is under way in a given field, or, in other words, *to determine what is being done or has been done elsewhere.* Likewise, it provides an easy means for keeping abreast of research findings. Through this mechanism voluntary coordination of research would be stimulated, and with resultant reduction if not elimination of undesirable duplication.

Broadly, the sum and substance of my comments is that the best and only way to obtain coordination in forest products research is through cooperation. This seems like a simple formula, but it is really a big order. It is an opportunity and a challenge to the Society for a unique service which it is in the best position to render.

Is the Society able and willing to organize to meet this opportunity and need?

General Discussion of Coordination in the Field of Forest Products Research

Dr. Harry F. Lewis (The Institute of Paper Chemistry): The suggestion has been made that the university and government laboratories confine their activities to what has been termed fundamental research and industrial laboratories confine their activities to applied research. While I can understand the difficulties involved when industry follows up on a process developed in and patented by a government agency, it seems to me that it would be extremely difficult to say "stop" to the research man in the government laboratory who conceived the idea behind the fundamental study and who has the imagination to project this study into an application. One way industry can take advantage of a development of this type is by means of improvement patents and the application of their own brand of know-how. This was precisely what happened 30 years ago when Gibbs and Conover, working in the Color Investigation Laboratory of the U. S. Department of Agriculture in Washington, D. C., took out the basic patent on the catalytic oxidation of naphthalene and proceeded with pilot plant testing.

At the same time we cannot say to industry "You stay out of the field of fundamental research." Had this been done, the vast operations of the chemical industry might never have been created. It was fundamental work by du Pont which created the nylon industry.

There can be no hard and fast distinctions here. It is of the utmost importance that developments in the field of pure science keep ahead of developments in the application of those developments; the first precedes the second. One result of World II is that we are dangerously close to the bottom of the barrel in the fields of the basic sciences. The expansion of these basic science frontiers must be carried out by the men and women who have the genius for frontier work regardless of the genesis of the pay check; at the same time, the application work should be left to those who have the genius for coming in behind and consolidating. There's work enough to be done by everyone—the important point is that pressure be applied where it is needed and by those best suited to apply the pressure.

Effective coordinated research in the field of forest products and wood utilization is handicapped today by our lack of fundamental knowledge in the field of lignin and of many related materials present in wood in lesser amounts. Likewise, our basic knowledge of bark is spotty, being confined to a few species and a few specific extractives. This Society can serve a real need by stimulating coordinated studies in these areas especially.

Prof. E. George Stern (Virginia Polytechnic Institute): I should like to comment on Mr. Elmendorf's paper. Proper training in performance of research at educational institutions requires active research of both fundamental and applied nature by the educators. Such educational research activities may lead to developments of a patentable nature. The educator, of course, cannot be deprived of his rights and privileges when his activities justify the issue of patents which may be considered part of proper remuneration. Should the educator have to cease his activities at the very moment when he is to be justly remunerated for his activities, nothing would prevent him from severing his ties with the educational institution and, as a consequence, no public institution would be in a position to hold successful research men. Hence, the acceptance of Mr. Elmendorf's recommendations would automatically lead to a depletion of competent research staffs of our educational institutions.

Mr. Elmendorf has not given a presentation of the actual conditions, according to which most of the publicly financed educational institutions handle their research. These institutions follow the practice of entering into con-

tracts with industry, which vary somewhat with the specific policies of the institutions, but make it entirely practical and feasible to make patent assignment to the cooperating industry and to reserve to the industry all rights to the research findings. As a matter of fact, this is a more or less common, justified and necessary practice, required to assure an utmost desirable close contact of educational institutions with industry. Without such contacts, proper education of future research men is not thinkable. For detailed statements concerning the research policies adopted by the various publicly financed and endowed educational and research institutions, reference may be made to the bulletin on "Investigation of Patent Practices" by the U. S. Department of Justice (1945).

As to possible duplication of research; such duplication may, under certain conditions, be entirely justified and even desirable, since different men may have different viewpoints by reasons of background and experience, thus may look at the subject matter with entirely different eyes. A practical example of this nature was a completely independent performance of some fundamental research by two men at two educational institutions under the sponsorship of a trade organization. Both investigators had similar approaches to the subject matter, but came to entirely different, not contradictory but supplementary, conclusions which might not have been advanced if the investigators had cooperated, or if one of them had abandoned his efforts on hearing of the activities by the other researcher. Thus, under certain conditions, duplication of effort may even be recommended and encouraged.

Prof. Frederick H. Vogel (Alabama Polytechnic Institute): I was very much interested in what Mr. Lewis had to say, but I want to add a thought to this discussion. I have been fortunate in seeing several sides of the research picture, having worked in both public and private research laboratories in various parts of the country.

There is a different value placed on the results of research by public agencies and by private organizations. Every private laboratory worthy of the name has a certain store of knowledge which it can count as assets. That attracts clients—the possibility of tapping particular data and ideas which may lead to patents, for example. Private laboratories could not be expected to publish such information, any more than they could pass out any other assets.

I hardly need to mention that prominent industrial laboratories, such as those of Westinghouse, General Electric and Dupont, and such well known service research organizations as the Teco and Elmendorf Laboratories, have a considerable fund of facts and "know how" held back for paying clients. We can't expect them to exchange all their ideas with us. Their personnel, on the other hand, is very much interested in publishing some of that information which will keep their companies before the eyes of the public. The administrator decides what to publish and what to hold back.

Public agencies have none of this problem. Theirs is a plan of working for both theoretical and practical results, and of publishing all they know as fast as they can get it into the presses.

There is a different fundamental aim in each group, and we can't reasonably expect private laboratories to open all their files of unpublished information to us.

Mr. Arthur L. Mottet (Long–Bell Lumber Company): Coordination of research with reference to avoidance of duplication is in my opinion relatively unimportant. Varied approaches to the same problem by different groups are highly desirable. The only type of duplication we should try to discourage is that which arises from plain ignorance of what has been done before in a specific field, and I believe that FPRS, with its publication and proposed abstracting service, is and will be performing an important function in this connection.

However, proper coordination of research with reference to the economic effect of the work, particularly as between publicly supported and privately supported work, as brought out by Mr. Elmendorf, is extremely important. As was pointed out, certain types of activity by the publicly financed groups can discourage private research, and it should also be emphasized that other types of activity by the publicly financed groups can have greatly stimulative effect on privately financed work. I am one of those who believe that public ef-

fort in the field of forest products research is still far below the saturation point and could be greatly increased with benefit. But proper coordination of public with private effort should certainly be given a great deal more emphasis in the over-all picture.

Prof. Hereford Garland (Michigan College of Mining and Technology): I should like to offer an amendment to Mr. Rishell's definition of coordination. It should include a basis for bi-lateral or group cooperation on problems of common interest. We all need to know what kinds of work are in progress at other research institutions. One way of gaining this information is to visit other laboratories and institutions. We, at the Michigan College of Mining and Technology, have had to use this method in forming a basis for our initial research program and we need this same type of information each year for program revision. Such repeated extensive travel is not a justifiable expenditure of research time and appropriations.

Informal contacts made at meetings such as this are of course helpful in research coordination, but this method is extremely limited. What is needed is formal machinery within the Forest Products Research Society for the annual exchange among research agencies of forest products research program information.

Mr. James F. Hamilton (Perkins Glue Company): Those of us who acquire our income from some phase of the forest products industry should have a very personal interest in this subject. From a long-range viewpoint, the markets for the products of each of our very own companies are very closely correlated to research efforts, whether conducted by our company or yours. The coordination of such research cannot help but redound to the benefit of the industry as a whole—and what helps this industry, helps each of us.

Mr. John H. Gividen (Dunbar Furniture Manufacturing Company): It is quite obvious that we should have more coordination in connection with research in the forest products field, for the simple reason that there has been so much independent thinking along this line and the application of the research has been more of an abstract matter and not practically applied. In other words, it was made a matter of record but not brought to the attention of the people who could make use of it. Because of this condition, it would certainly be a step forward if we brought into the picture the spirit of coordination.

TECHNICAL SESSION V

Tuesday Afternoon, March 23, 1948

Open Forum: Finishes for Furniture

Moderator: John H. Gividen, Vice President, Dunbar Furniture Company, Berne, Indiana

Recorder: W. Burdette Wilkins, Consulting Engineer, Ridgewood, New Jersey *(Chairman, Northeastern Section, FPRS)*

Discussion Leaders:

R. E. Prince, Executive Vice President, Stewart–Mowry Company, Chicago, Illinois

W. E. Martin, Director, Technical Service Department, Grand Rapids Varnish Corporation, Grand Rapids, Michigan

W. S. Robertson, Supervisor, Chicago Regional Office, E. I. duPont de Nemours and Company, Chicago, Illinos

F. H. Thomas, Superintendent, Furniture Technical Service Department, The Sherwin–Williams Company, Chicago, Illinois

R. I. Quigley, Vice President, The Lilly Company, High Point, North Carolina

General Discussion—See p. 165

Historical Development of Furniture Finishes

R. E. Prince

Executive Vice President, Stewart–Mowry Company, Chicago, Illinois

AS "LEAD-OFF" man in this open-forum discussion, I have been asked to discuss the historical development of furniture finishes, with special reference to improvements in materials and techniques during the last quarter century.

Generally speaking, it is usually the first speaker's privilege to go way back into the history of the product he is discussing and portray the progress made since biblical days or the era of King Tut. However, as I have only five minutes allotted me, I dare not go so far back, but shall talk briefly of furniture from the 18th Century to the present time.

Prior to and during Mid-Victorian days, furniture finishing consisted of the application of self-made stains, occasionally crude fillers, and shellac in the form of French Varnish. The workman was usually an artist and learned his art from his immediate ancestor. Stains and varnishes, as we know them, had not been discovered, and fillers were seldom used. Color effects were obtained by the use of wood-extracted dyes or dyes made from insects. Occasionally, wood was treated only with oils, which were rubbed in and aged. The application of shellac or French Varnish was done by experienced finishers, who diligently rubbed the wood surface with coats of this material until a high polish was obtained. As we examine what we now call antiques, we realize that this system was not bad practice at all. In fact, beautiful and durable finishes were obtained in this manner. If the artisans of that period had had our technique in veneer manufacturing and our modern glues, I am sure that all of you who know anything about authentic antique furniture will agree that no fault could be found with 17th and 18th Century finishes.

Our forefathers, who started the great furniture industry in this country, were extensive users of linseed oil. They would spend days rubbing their handicrafts with oil, until they attained what was then thought to be a superior protective coating. Possibly it was, but times and technology improved the working tools of the industry and, more than a half century ago, someone discovered that fossil gums from India, Singapore or Africa could be melted and mixed with linseed oil to produce what we now know as varnish. It was also found that oil or bitulithic-type stains and fillers could be prepared with earths mixed in linseed oil. Naturally, these products improved the finish, but they were exceedingly slow in drying; nothing to meet today's production schedules.

As the paint and varnish industry grew, its "know-how" kept in step with the times. New oils, gums and resins were introduced, and during the last 35 to 40 years varnishes made with tung oil came into being. These varnishes were readily accepted by the furniture manufacturer because of their drying speed. A few years prior to the introduction of tung oil, another product of importance was added to the list of furniture finishes. I refer to aniline stains, made synthetically from coal tar. This development was indeed a boon to the industry. We now had, for our selection, permanent dyes to stain our woods and fast curing varnishes that could be rubbed and polished to a queen's taste.

But, as is always the case when "old man progress" is involved, these tools were still not good enough. A world war brought to light a product made from vegetable fibers. It has been known for some time that cellulose, or cotton fiber, could be treated with sulphuric and nitric acid to form a product that became soluble in various alcohols and esters. The resultant material, when applied on steel, wood, or fiber, produced films that gave transparent and promising effects. Unfortunately, these

films were not particularly durable, nor were they of any great thickness.

These faults were soon corrected, however, although by sheer accident. A workman in one of the plants making these products cleaned a mixing kettle with caustic soda and neglected to remove all of the caustic before again charging the kettle with nirocellulose and solvents. This seemingly careless mistake caused the product he then prepared to become changed from a very viscose solution to a very thin compound. Naturally, the workman was blamed for not making the proper mixture, but, when checked by the chemist in charge, it was found to contain the correct amounts of all ingredients and weeks passed before the phenomenon was satisfactorily explained. With the discovery that caustic soda would reduce the viscosity of nitrocellulose in solution, the lacquer industry came into being. Later, gums were added to nitrocellulose, plasticizers were developed to give elastic films, and good rubbing and polishing lacquer became widely used.

Aniline dyes of a water-soluble nature were in wide use at this time; they were permanent and easily made by the furniture finishers. Lacquers dried very rapidly, but water stains were slow. So, as you know, the paint manufacturer found ways and means of solubilizing water aniline dyes in spirits, retaining a great deal of their light-permanency with quick drying and non-grain-raising effects.

Modern furniture, or blond and natural effects, came into use about 1932. This required a new technique, since it was necessary to bleach the wood prior to finishing it with lacquers. As you all know, this procedure was mastered and is in wide use today. Various methods of bleaching, staining, semi-painting and glazing are probably used in every factory, to produce light-color effects for modernizing furniture finishes.

I have not said much about fillers, nor have I said anything about new synthetic varnish finishes, which are coming along at this time. These subjects will presumably be mentioned in other papers this afternoon.

Hot application of lacquers should be explained, to acquaint you with this modern method of applying heavy coats in one spray application. Fillers should be discussed and the truth told to you as consumers of this important wood finishing product.

In conclusion, may I say, as a representative varnish and lacquer producer, that time will not stand still. Many products of improved quality, adaptability, and even faster production possibilities are on the varnish and lacquer manufacturer's slate today.

Mr. Chairman, I hope I have key-noted this meeting with these brief remarks. I know that those who follow are ready to acquaint our audience with new and valuable techniques in finishing wood furniture.

Finishes Resistant to Alcohols, Acids, and Similar Deteriorating Agents

W. E. Martin

Director, Technical Service Department, Grand Rapids Varnish Corporation, Grand Rapids, Michigan

I HAVE assumed that your program committee, in assigning me the subject of resistant finishes, had in mind resistance to the more unusual destructive agents—chemicals, solvents, medicinals, perfumes, cosmetics, etc. It should be remembered that, among the "other destructive agents" affecting the serviceability of finishes, the most common and serious is ordinary wear and tear. A finish which is easily marred or scratched, which fails by checking due to temperature or moisture change, or is readily damaged by water is not of much interest, even if it has high resistance to a whole range of unusual destructive agents.

The advantage of resistant finishes is fairly obvious. In selecting furniture and equipment for homes, offices, institutions, and public buildings, we are very conscious of appearance values. Aside from the elements of design, appearance depends on the condition of the surface. With painted or finished wood, it depends on a thin film of finishing material, from one to three thousandths of an inch in thickness. If the finish is damaged or destroyed, the value of the piece of furniture or equipment is reduced. The advantage of a resistant finish is that it is less susceptible than other types to damage by various destructive agents. So far as I know there is no other advantage.

The disadvantages are primarily in the finishing operations. Nearly all the more resistant type finishes introduce some difficulty in application, drying, build, ease of sanding, rubbing and polishing; also they are more expensive than the other types. Since their use tends to limit output or increase cost, or both, it is not surprising that furniture manufacturers have not adopted them more widely.

In considering the desirability or need of a high-resistance finish, it is logical to question what type or types of resistance are actually important. Determination of this point depends, of course, on what conditions the furniture is likely to meet in service. For ordinary household furniture, resistance to strong acids and alkalies is certainly of little importance, and resistance to straight alcohol is not too important. We consider that good resistance to straight whiskey, or 50 percent alcohol, is usually sufficient. Actually, damage by beverages is more likely to be a case of water injury. However, a dressing table may be damaged by perfume spots, which are more potent than straight alcohol due to the presence of slow evaporating essential oils of high solvency, or by nail polish and removers, which contain acetone. For good resistance to these agents, we must use the best of resistant-type finishes.

For hotels, restaurants, bars, and public buildings the need for durable finishes becomes considerably more important. This is the case, not because furniture and equipment in these locations necessarily encounter a greater range of destructive agents, but rather because people are more careless in such places than at home. The need for highly resistant finishes becomes more important for hospital, medical, dental, and laboratory equipment. In general, it is only for these purposes that we encounter any substantial demand for finishes of highest resistance values.

You may be interested in some discussion of the various types of resistant finish that are used. We are limited in the types that can be applied to wood with ordinary finishing methods, due to the fact that high temperatures cannot be used in baking or curing. In this respect, we are at a disadvantage with certain plastic compositions on which the surface layer is cured under high temperature and pressure.

Lacquers are available with good resistance to hot and cold water, beverage alcohol, fruit

acids, mild alkaline cleaners, food fats, and hot dishes. They are damaged by strong solvents, such as perfumes and nail polish remover, but have proven very satisfactory for household furniture generally.

Baking urea types, with special activators, have gained considerable acceptance. They bake in from 60 to 90 minutes at temperatures of 150° F. down to 120° F. They have good resistance to beverage alcohol, and fair resistance to perfumes and nail polish remover. They are not damaged by mild acids and alkalies, but are not especially recommended for laboratory furniture. Their use involves some difficulties in production, such as susceptibility to blistering and tendency to haze or cloud with rubbing. These difficulties can be overcome by proper manipulation.

A straight phenolic coating, which cures at about the same schedule as the baking ureas, is outstanding among the presently available types. It is quite new and has as yet only rather limited use. It is very good in resistance to 95 percent alcohol, hydrocarbon solvents, esters, ketones, dilute acids, and alkalies. Its chief disadvantage is a lack of compatibility with the stains, fillers and glazes used in wood finishing.

The well known tung-oil phenolic air-drying varnishes are among the most practical and widely used of the resistant finishes. They resist 50 percent alcohol, fairly strong acids, and alkalies, but are slow drying and requie special techniques of rubbing and polishing. They have had good acceptance for institutional furniture, restaurant and bar equipment, and laboratory equipment.

We consider that resistance to concentrated acids and alkalies is a special problem usually of interest only for laboratory furniture. There are no truly practical transparent wood-finishing materials of high resistance. Satisfactory results for vertical surfaces are obtained with the baking phenolic type finish previously mentioned, as well as with an air-drying type of finish containing chlorinated rubber. Laboratory table or bench tops should not be made of wood.

One of the most needed types of resistance is to cigarette burns. This is very difficult for two reasons—the low heat conductivity of wood, and the fact that all our practical finishing materials are organic, hence combustible. One solution is lamination with a thin layer of metal, such as aluminum foil, under a thin surface veneer of wood. This construction, finished with ureas or phenolics, is reasonably free from serious damage by cigarette burn.

Low-Bake Synthetic Finishes For Furniture

W. S. Robertson

Supervisor, Chicago Regional Office, E. I. duPont de Nemours and Company, Chicago, Illinois

THERE is a definite increase in the interest in and use of low-bake synthetic finishes for wood furniture, in place of the usual lacquer or varnish finishes. This development is due to the growing trend toward conveyorized operations, as well as the desire for increased production and lower costs in the furniture industry.

Low-bake synthetic furniture finishes are usually resin combinations, principally alkyd and urea-formaldehyde resins. They contain from 40 to 50 percent non-volatile solids and are usually sold at ready-to-spray viscosity.

These synthetics do not air dry satisfactorily. In addition to requiring heat, they also require the use of an accelerator to effect complete curing or drying at the low temperatures necessary with wood furniture. This accelerator is added either by the manufacturer, or by the consumer just prior to use. In the latter case, a more potent accelerator can be used, permitting shorter bakes or lower temperatures. Baking schedules will vary from 2 to 6 hours at 120° F. or from 1 to 1½ hours at 150° F., depending on the type of accelerator used and the particular requirements of each customer. These finishes do not cure satisfactorily at temperatures below 120° F.

During the baking operation, it is necessary to maintain from 30 to 40 percent relative humidity in the oven. This is done to protect the glue joints and to minimize any change in the moisture content of the wood. The use of today's improved adhesives, particularly of the synthetic type, has further reduced the difficulties of baking furniture, but the introduction of moisture is still considered necessary, particularly at the higher temperatures. It is not introduced to aid in the drying of the synthetic finish.

About the only precaution necessary in baking synthetic finishes is that they be allowed to flash or air dry for at least 30 minutes before entering the heat. This enables most of the solvents to evaporate and permits the film to set-up tack-free, thus minimizing the possibility of blistering in the baking operation. After baking, it is necessary to allow the work to cool to room temperature (at least 30 minutes) before rubbing and processing.

The usual finishing system consists of regular stains, fillers, etc., one coat of sealer, and one coat of synthetic finish. Because of their high solids content and the fact that they spray and flow more like a varnish, one coat of finish gives adequate build for a thorough rub job. Synthetics rub and process very well and are available in either clear or semi-gloss finishes.

Synthetic finishes usually replace lacquer, because of the substantial saving in cost which they offer. It has been our experience that these synthetic finishes will show savings as high as 30 percent in material top-coat costs alone, in comparison with a two-coat lacquer system. There is also the additional saving due to less handling and one less spray operation.

From the standpoint of quality, synthetics are at least the equal of good grade lacquer in general durability, toughness, hardness and cold-crack resistance. In addition, they are definitely superior in resistance to alcohol, food stains, nail polish remover, and similar reagents.

Normally there is no material cost saving when a synthetic replaces a varnish, but there are production savings plus a big improvement in quality. In addition to getting lacquer toughness and durability at no increase in cost, you get much faster and more positive drying and much greater print resistance.

The question is frequently raised as to whether synthetics can be patched and repaired satisfactorily. The answer is that they can. They may be burned in with stick shellac, just as a lacquer or varnish is. When necessary, they may also be recoated, but only once. Too heavy

a film will increase the danger of cold cracking, as it will with any other type of finish.

Synthetic finishes are, of course, particularly well adopted to conveyorized operations. However, the extent to which a conveyor is used will depend on each individual manufacturer's requirements. Some concerns have conveyors for all operations from the white wood to the rubbing line, while others will just conveyorize the baking operation, or only the spraying operation and bake the synthetic in a box-type oven. Some concerns do not have any conveyor at all, and bake the synthetic in a homemade box oven heated with Modine-type heaters. Synthetics are very flexible and will fit into almost any requirement or condition.

One interesting special use for low-bake furniture synthetics is in connection with a new method of panel construction used in obtaining a burn-proof table or desk top. This method consists of laminating a thin sheet of aluminum immediately under the face veneer. The aluminum rapidly absorbs and dissipates the heat that comes through the veneer from a burning cigarette. Finishing is done in the usual manner, but it is necessary to use a synthetic finish in order to get the maximum in burn-proof properties. The synthetic used for this purpose is longer in oil than the regular furniture synthetics and requires about twice the baking time at any given temperature.

For all of these reasons, we believe you will be hearing a great deal more about low-bake synthetic finishes for furniture in the next few years.

Materials and Methods For Finishing Radio Cabinets and Similar Products

F. H. Thomas

Superintendent, Furniture Technical Service Department, The Sherwin–Williams Company, Chicago, Illinois

RADIO cabinets are finished in much the same manner as many lines of case goods and occasional pieces. Their uniformity of size and construction makes them ideally suited to conveyorized finishing, and with conveyors it is of course advantageous to use as fast drying materials as possible. Hence, most radio cabinet finishing schedules are very fast.

I have chosen three typical finishing systems to discuss with you. All three are lacquer systems, lacquer still being the most popular finishing material where speed is required.

I. Walnut or Mahogany Finish

This is a schedule used on walnut or mahogany cabinets in a medium to dark color of finish. A mahogany cabinet would probably consist of mahogany plywood for the sides, front, and top and gum wood, tupelo and poplar, some solid, some plywood, for the base, posts, record compartment, backs of doors, etc.

The first operation in this schedule (Op. 1) is to spray a *Sap Stain* on the supplementary woods, in order to blend them over to the color of the mahogany veneer. It is good practice to prestain as many of these odd parts as possible in the cabinet room before the cabinet is brought into the finishing room; then the spray man has only to spray sap stain on the sapwood (such as in walnut wood) and can proceed immediately with the spraying of the *Body Stain* (Op. 2). No drying is required following the application of the Sap Stain.

The Body Stain carries the basic color of the finish and is mixed prior to spraying, in the proportion of about 1 part shellac to 7 parts stain, to make a combination stain and wash-coat. This dries in 15 to 20 minutes and is then sanded with 6/0 paper (Op. 3). The *Filler*, reduced about 7 pounds per gallon of naphtha, is then sprayed (Op. 4), wiped and dried for 1 to 4 hours, depending on the type of filler used.

As the next step, a 21 percent solids *Lacquer Sealer* is sprayed on the cabinet (Op. 5), dried for one hour, and then sanded with 6/0 paper (Op. 6). Patching is then done where necessary with earth colors and French polish (Op. 7); no drying is required.

The next operation (Op. 8) is to even up the color of the cabinet by spraying with *Lacquer Shading Stain*. Very little shading is necessary if a good job of prestaining has been done at the beginning of the schedule (Op. 1). No drying time is required for the shading stain, which is followed by the application of a coat of a 24 percent *Bright Rubbed Effect Lacquer* (Op. 9). This is allowed to dry for one hour, after which the decals of the name of the radio, to identify dials, etc., are applied (Op. 10). This requires no drying time, and the second coat of 24 percent Lacquer is immediately applied (Op. 11). This final coat is allowed to air dry overnight before rubbing.

The following morning the cabinet is machine sanded with 360 sandpaper, oil and naphtha (Op. 12). Then, if a soft luster is desired, the cabinet is hand rubbed with 4/0 steel wool and *Brown Wax* (Op. 13a); a high luster is obtained by rubbing with *Brown Compound* and cleaning up with *Brown Polish* (Op. 13b).

The whole finishing schedule can be accomlished in 24 hours. The time of application of all materials is often as little as 4 hours.

II. Bleached Mahogany Finish

There is a considerable demand for bleached finishes, which can be obtained by the application of the following schedule:

The entire cabinet is sprayed with a *Chemical Bleach* and allowed to dry overnight (Op. 1). It is then sanded with 6/0 paper (Op. 2). A wash coat of *Water White Lacquer Sealer,* reduced about 1 part sealer to 3 parts thinner, is then applied over the entire cabinet (Op. 3), and allowed to dry for one-half hour. It is next sanded again with 6/0 paper (Op. 4) and filled with the desired color of *Filler* (Op. 5), after which it is air dried for 1 to 4 hours, depending on the type of filler, and then sprayed with a coat of *Water White Lacquer Sealer,* full body (Op. 6). This coat dries in 1 hour, after which it is sanded with 6/0 sandpaper (Op. 7).

The final finish usually comprises two coats of *Water White Waxing Lacquer* (Ops. 8 & 9), allowing 1 to 2 hours air drying between coats. The final coat should be allowed to dry overnight, but can be sanded and waxed two hours after application. The final operations are to dry sand with 6/0 sand paper (Op. 10) and then rub with 4/0 steel wool and *Blond Wax* (Op. 11). The over-all time for this finish is 24 to 36 hours.

III. Simulated Bleached Finish on Mahogany

The bleaching operation outlined above is slow, messy, and expensive. Hence, there has been a desire to produce a bleached effect without actually bleaching. This method is outlined below.

The cabinet is first sprayed all over with a coat of *Blond Lacquer Toner* (Op. 1). This is a fairly heavily pigmented lacquer that hides the red color of the mahogany and sets up quickly, so that it does not flow into and fill up the pores of the wood. It is allowed to air dry about 1 hour and is then sanded with 6/0 paper (Op. 2).

The pores of the wood are then brushed out well, so as to open them up for filling (Op. 3). The subsequent steps of applying the desired color of filler, sealing, sanding, applying two coats of Waxing Lacquer, sanding, and rubbing with steel wool and Blond Wax are the same as operations 5 to 11 in the Bleached Mahogany finishing schedule described above.

The over-all time of completing this finish is as low as 8 hours. All finishing materials can be applied in as short a time as 4 hours. The simulated bleached finish, although it does not look as nice as a genuine bleached finish, does have the advantage of holding its color better on exposure to sunlight. The actual bleached finish will darken more readily.

FOREST PRODUCTS RESEARCH SOCIETY

Some Simple Testing Methods For the User of Wood Finishing Materials

R. I. Quigley

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THE question, "Should we, as users of finishing materials, set up a laboratory for testing these products?", is one which I have been asked many times. At first thought, the answer would seem to be, "No, as a user of finishing materials you need not worry about the quality or uniformity of these materials, because you are buying from a reputable manufacturer who has ample facilities for properly formulating and controlling the product you receive." However, I do not think that is always the correct answer.

It is true that reputable manufacturers of finishing materials do take every possible precaution to insure the proper formulation and manufacture of their products, because their reputation depends upon such quality control, and because poor finishing materials could cause damage far in excess of the cost of the material itself. However, from the standpoint of a concern which is engaged in producing finishing materials, and from past experience with companies which manufacture wood products and which have set up means of testing the products they use, we believe that such testing facilities are a good thing if the person in charge of them is competent. Such a testing program could save, and has saved, money both for the user and the producer of finishing materials.

I believe that most persons who have been engaged in manufacturing and selling finishing materials (especially for wood) will agree with me that many, and perhaps the majority, of complaints received from users of their products are unjustified, although the complaints have been honestly made. Many factors besides the materials themselves can influence the results obtained with finishing materials. Some of these influencing factors are preparation and moisture content of the wood itself, proper or improper glue sizing, control or lack of control of temperature and humidity conditions in the finishing area, and proper or improper application of finishing materials. Our experience has been that, where adequate means of testing have been set up by the user, complaints have greatly decreased.

A program of testing could be large and elaborate, or small and simple, according to the size and needs of the particular concern. It might be fitted in as part of a larger testing laboratory arrangement, in which other items, such as adhesives, abrasives, fabrics, shipping containers, and various other goods used by the manufacturer of wood products, are tested.

A laboratory on such a scale would require considerable equipment and a technically trained personnel in order that it function properly. Briefly, such a laboratory would probably have the following equipment for testing finishing materials:

1. A small spray booth and spray equipment for application of materials to be tested.

2. A small electric oven, with accurate temperature control and, preferably, humidity control. This would be used for duplicating drying conditions in the plant where ovens, or "hot-boxes," are employed, for determining solids or non-volatiles, and for making cold-check tests on coatings.

3. An electric freezer, capable of maintaining temperatures of minus 5°F., for use in making cold check tests.

4. A Fade-ometer, Weather-ometer, or similar device. The Fade-ometer, or other device using ultra violet light, is employed for testing light stability of stains and colored finishing materials, as well as for investigating the ability of coatings to withstand discoloration when exposed to sunlight or other strong light. This is important, particularly on bleached or light-

colored furniture, and especially on the modern functional furniture where pieces are grouped close together and where additional pieces are added to a group at a later date. The Weather-ometer can be used as a Fade-ometer and also can give valuable information on the weathering performance of coatings. The question might be raised as to the need of this kind of test for furniture to be used inside of houses or buildings. However, we have found this information valuable, inasmuch as in certain sections of the country, and particularly the South, prolonged conditions of high relative humidity prevail at certain times; even though the furniture is indoors it can suffer damage from the high moisture content of the atmosphere, if not properly finished.

5. Devices for determining and checking viscosity. There are many different kinds of apparatus for this, but a Gardner Bubble Viscometer and a No. 4 Ford Cup and stop watch will probably meet all the requirements here.

6. A Sward Hardness Rocker, or other means for testing hardness of films.

7. A set of standardized weights for testing print resistance of coatings.

8. A Gloss Meter for checking the gloss, or sheen, of coatings.

9. Devices for testing toughness of coatings.

10. Means of checking elasticity of films.

11. Means and space for sampling, labelling, and filing samples from various shipments.

The foregoing list of equipment is far from complete and could be greatly extended, if desired. However, as said before, a laboratory employing such facilities for varied testing would require well-trained technicians, or the results obtained would probably be worse than useless.

To illustrate this point, let us consider testing for cold checking. This test was originally developed to determine the ability of a finish to withstand pronounced and sudden changes in temperature. However, it is probably used now more as an indicator of the ultimate life of a finish. There is no standard procedure as yet for this test, although the National Paint, Varnish and Lacquer Association has a committee working on the subject of developing a standard method of conducting it. Many factors besides the temperatures used and the times that the test panels are kept in the ovens or freezers influence the results obtained. For instance, consideration must be given to the kind of wood used, its moisture content, the film thickness of the coatings being tested, the length of time that the coatings have dried before being tested, and other influences; even humidity conditions at the time coatings were applied have a bearing on the cold-check performance. From this it can be readily seen that, until very rigid standards of procedure are set up, the test can be quite meaningless. It should be used only in comparing materials which are applied at the same time and in the same manner and preferably on the same piece of wood, and by a person who has had considerable experience both with conducting the test and reading the results obtained.

The question also arises as to how the furniture manufacturer can test incoming shipments of finishing materials, by simple means and equipment, to determine whether or not they are uniform in quality. He may also wish to know what simple tests can be made to compare the products being used with new products offered, as well as what further testing might be advisable that would require services of a consulting laboratory.

In any test procedure, it is first necessary that the goods be sampled. In doing this one must be sure that if there is more than one production batch in the shipment, a sample is taken from each batch. Most manufacturers of finishing materials show the production batch numbers on each container. The containers should be thoroughly stirred before withdrawing the sample, which should then be placed in a bottle with an airtight cap. If it is desired to keep batch samples for future reference, the bottle should be marked to show number and name of material, date received, and production batch number. From the initial shipment of any material, standard samples should be taken and properly labelled so that they may be used for comparison against later shipments. Several small samples are preferable to one large sample, since they need not be opened and exposed to the air as often and can be kept better.

In considering a minimum number of tests by which the buyer of finishing materials can determine the uniformity of successive ship-

ments, without the necessity for extensive equipment, I suggest the following:

1. Clear coatings can be quickly checked for color, by pouring both the standard and the sample in test tubes or viscosity tubes of the same size and comparing them visually. It is, of course, most important that color of coating materials be uniform, particularly when used on bleached or blonde furniture.

2. Uniform viscosity is important in the coating materials because viscosity influences flow, sprayability, and film thickness. Of the many methods of measuring viscosity, perhaps the most adaptable for use in the furniture plant are the rising-bubble type of viscometer and the cup type, such as the No. 4 Ford Cup. In measuring viscosity, it is important that temperature be controlled, as the viscosity of coating materials varies greatly with changes in temperature. Viscosity measurements are usually taken when the material being tested and the instruments have been brought to a temperature of 77°F.

The rising-bubble type of viscometer consists of glass tubes, which are filled with the liquid to be tested up to an etched mark and then stoppered, leaving a small air bubble in the tube. On inverting the tube, the bubble rises. The rate of rise in the sample under test is compared with that in liquids of standardized viscosity kept in sealed tubes. This method is quick and, while not extremely accurate, is sufficiently so for the purpose. The Ford Cup is a small cylindrical vessel with an orifice in the center of the bottom. The time required for a full cup of material to run out through the orifice is measured with a stop watch. It might be noted here that some types of materials have a tendency to thin out, or decrease in viscosity, on aging, while others "body", or gain in viscosity, on long standing. It is well, therefore, to note and record the viscosity of the initial shipment and refer to that, rather than to check the standard each time a new shipment is tested.

3. Specific gravity of shipments of materials can be quickly tested by means of a hydrometer or a Westphal balance. Again, the temperature must be controlled in making measurements. While the specific gravity of succeeding shipments should show no more than very slight variations, it must be remembered that some lacquer manufacturers, particularly those in the South, make certain changes in their solvent formulation from winter to summer, and vice versa. This is done to counter the effects of changes of temperature and relative humidity in the different seasons. Such differences in solvent formulation might change the specific gravity of the product without altering the actual amount of solids in the material.

4. Measuring the solid content of a material is a simple test, the only special equipment needed being an accurate balance and a small oven. Most furniture factories have these for use in determining the moisture content of wood. A small amount of the material to be tested, usually about 2 or 3 grams, is weighed in a metal dish which has previously been weighed. The weight of the dish is subtracted from the total weight of the dish and material, giving the weight of the material. The material is then placed in an oven for a certain period. It is suggested that for most finishing materials a temperature of 250°F. for two hours, or 150°F. overnight, will give proper results. After being taken from the oven, the dish and residue are again weighed and the weight of the residue computed. This, divided by the weight of the material before being placed in the oven, gives the percentage of solid content.

5. The uniformity of sheen, or degree of gloss, of succeeding shipments is particularly important in top coatings, but may also be noted as a test for uniformity in shipments of undercoatings, such as sealers. This may be tested simply by spraying a sample from the new shipment alongside the standard, allowing them to dry, and then inspecting them visually. Care should be taken that the sample and the standard are applied in films of approximately the same thickness. It would be well to use a gloss-meter and to compare the reading obtained for each shipment with the recorded reading of the standard or first shipment.

6. Print tests are important in evaluating coating materials. It is suggested that the sample from the shipment being tested be sprayed alongside the standard on a prepared panel, and the two films allowed to dry under

the same conditions that prevail in production. Weights should then be placed on each dried film over a small pad, such as a piece of coarse cloth or two or three thicknesses of Kimpack wadding. The weights can be made from steel shafting, cut to lengths to give pressures of one or two pounds per square inch, or more, if desired. The weights may be removed at intervals and the panels inspected for an impression in the film. The weights are usually allowed to remain on the panels overnight before the final inspection is made. A film that will withstand a weight of two pounds per square inch will usually meet the requirements of packing and shipping. The results of this test depend upon the thickness of the coating applied to the panel. It is important that sample and standard be applied as nearly alike as possible, with the film thickness comparable to that used in production.

7. Sealers should be tested for sanding. The sample being checked and the standard should be sprayed on a prepared panel, preferably a wood panel which has been filled. After the coatings have dried for the proper length of time, which should be approximately the time the sealer is given to dry in production, they should be sanded. Use a clean piece of finishing paper for each spray-out, and make the same number of strokes, using as nearly as possible, the same pressure on the sandpaper in each case. Notice if there is any difference in drag in the sanding of the two films. Notice also if there is more sand dust from one film than from the other. Also, examine the pieces of sandpaper to see if the grit on one piece is filled up more than on the other.

While lacquers are not always sanded when used in production, they may also be given the sandpaper test as a check on uniformity. In this case, the drying time before sanding should be greater than in the case of sealers.

The above tests should establish quite well whether or not the shipment in question is up to standard. The tests can all be performed within 24 hours after the shipment has been received. While the tests are being run, observations can be made as to the spraying qualities and the non-settling qualities of the material. Also, the panels on which print tests were made can be rubbed to determine any variation in rubbing qualities and clarity of film after rubbing.

It must be remembered that, while the foregoing tests are useful in checking uniformity of goods received, differences in results obtained in some of them are not necessarily to be taken as indicative of better or poorer quality. As an example, a lacquer might be higher or lower in viscosity without being better or poorer in quality. The final judgement depends on what viscosity gives the best results on the particular job. Also, one sealer might be harder sanding than another, and yet do a better job and contribute to a better finish.

To some furniture manufacturers certain qualities in finishing materials are paramount, while different qualities are more important to others. It would be difficult to find a coating material in which the optimum in all qualities is obtained. If special excellence in some one or two requirements is stressed particularly, it may be obtained only at a sacrifice of other qualities which are less important to the particular user. So it is necessary, when comparing various finishing materials, that one know which qualities are most important to him, at the same time making certain that the material which best meets these particular requirements is up to useable standards in other respects.

In testing new finishing materials against products already in use, a number of additional tests may be applied. In such competitive testing, I suggest the following additional tests:

1. Non-blushing
2. Flow and levelling
3. Adhesion, toughness, and mar resistance
4. Clarity of finish before and after rubbing
5. Fullness of film or build and shrinkage
6. Coverage or mileage
7. Water and alcohol resistance
8. Odor
9. Color and clarity on aging
   a. Dark exposure
   b. Sunlight or ultra violet exposure
10. Stability of materials in storage
    a. Changes in viscosity, color, drying, etc.

Without the aid of special equipment, many of the above tests depend on the experience

of the person doing the testing and his ability to read results correctly. This is gained mainly through practice. Furthermore, the materials being tested must be applied alike or results are unreliable.

Without the aid of a temperature- and humidity-controlled room or box, about the only way to test for non-blush character is to pick a damp day when the relative humidity is 75 percent or higher, and spray the materials being tested in full wet even coats. Some materials may be found which blush in the early stages of drying, but which clear up when dry. In others, the blush may remain after the film has dried.

Flow and levelling can best be judged by visual inspection after the materials have been applied. Such application should preferably be made to panels prepared with the same undercoat used in production. Sometimes flow or lack of flow can be discerned better when the materials are applied to a black glass plate.

The old test for toughness and adhesion, the fingernail test, is still much used by protective coating technicians, in spite of the fact that they may have various kinds of equipment at hand for doing the job. Another familiar test is to draw a series of parallel lines about 1/16 inch apart through the finish with a penknife. Another series of parallel lines the same distance apart are drawn through the first lines and at a wide angle to them. This crosshatched area is then rubbed vigorously with a rough cloth to see if any of the coating is removed from the surface below.

Clarity in a coating may depend on many factors, such as degree of gloss, flow, pigmentation of the coating as in flattened materials, and the compatability of various ingredients of the material. Some coatings do not rub clearly because they may soften under the heat generated by rubbing, or may be partially soluble in the rubbing materials and retain some of them. Coatings are usually checked for clarity before and after rubbing. In making a visual inspection for clarity, it is often helpful to view the reflection of the crossbars of a window in the applied coating film.

In considering fullness of finish or build, the user of finishing materials is primarily concerned with appearance. Actual measurement of film thickness does not always give the true answer. Some coating materials "bridge" better than others and give the appearance of a thicker film. It is suggested that panels being checked for this quality be held for 30 days before passing final judgement. This is to permit the finish to become thoroughly dried and to allow for whatever shrinkage is going to occur.

Coverage or "mileage" of coatings is probably best tested under plant conditions by actually using a measured amount of the materials in a production run. In doing this, it is best to use at least five gallons of each product being compared. In comparisons of coverage, one should also note the build and final appearance of the finished pieces, as the material which gives greater "mileage" may be deficient in film thickness and build.

In checking water and alcohol resistance, films should be aged a minimum of two weeks and preferably 30 days before being tested. Most furniture will not be used within 30 days after it is finished, and the characteristics of the films in regard to resistance to water or alcohol may be entirely changed after that drying period. A simple test is to make a puddle of water or alcohol, whichever is being considered, on the coatings to be tested; an ordinary drinking glass is then placed in this puddle and allowed to remain until all of the liquid has evaporated. If 190-proof alcohol is to be used, it should be reduced with an equal amount of water to give the approximate strength of beverage alcohol. The coating should be inspected for whitening at intervals and, after the liquid has evaporated, for recovery from any whitening. The ease or difficulty with which spots can be removed by rubbing or buffing should also be noted.

If there is any indication that odor of a material is obnoxious, it should be checked in the finishing room to make certain that the material will not be a source of irritation and discomfort to the workmen.

The manufacturer of bleached or light-colored furniture will want to know whether his coatings will discolor when exposed to strong light. It is also important for him to know whether they will discolor in darkness, as when enclosed in a shipping carton. With-

out the aid of ultra-violet light, sunlight can be used in making the test, although it takes longer. The materials to be compared should be sprayed on the same panel, which has first been coated with a white lacquer or undercoat. After the coatings have dried, the middle section of the panel should be covered with a heavy, dark paper in such a manner that portions of both materials are covered and the rest left exposed to light. The edges of the paper should be securely bound with tape to prevent light from seeping under the covering. The panel should be in such a position as to receive a maximum amount of sunlight. The paper covering can be partially removed at intervals for inspection, and the test can be continued as long as desired. It may take days, or even weeks, before results are noticeable, depending on the amount of sunlight available. It might be noted here that some coating materials, while having excellent color retention on exposure to light, darken considerably when kept in total darkness. Hence, the covered portions of the panels should be inspected as carefully as the exposed portions.

The furniture manufacturer hears more and more about cold-check tests on finishing materials. The suggestion is made here that, if he is interested in this test on his finish and does not have the equipment or the experienced personnel to run it, he send his materials or finished panels to a consulting chemical laboratory. He may want his whole system of finish tested, or various materials tested separately. If the testing is done by an outside laboratory, he should request detailed information as to how the test was run. The number of cycles that a material will pass in a cold-check test means very little unless one knows how the test was conducted.

General Discussion of Finishes for Furniture

Mr. Melville B. Wells (Aetna Plywood and Veneer Company): The use of temperatures in excess of 120° F. with relative humidities of 30 to 40 percent has been indicated for the fast drying of certain finishes on wood furniture. The ovens for such work should have automatic temperature and humidity controls, so that the relative humidity may be kept reasonably near that at which the moisture content of the wood will be in equilibrium. Otherwise, warping and other difficulties resulting from dimensional changes are probable.

Mr. W. E. Martin: The furniture manufacturer who is considering baking or force-drying equipment should be careful to obtain efficient ovens. This means a uniform circulation of moving heated air. It should not be assumed that because a thermometer hung in the oven reaches the desired temperature the oven is efficient or satisfactory. A room or a space partitioned off and heated with radiators only, without good air circulation, is not an efficient oven. The furniture manufacturer ought to have his oven, and especially the circulating system, designed by a competent oven man or heating engineer.

Mr. John C. Moore (National Paint, Varnish and Lacquer Association): I should like to ask about the feasibility of marking furniture to indicate the type, grade, and manufacturer of the finish which has been applied.

Mr. John H. Givіden (Dunbar Furniture Company): The principal reason that furniture manufacturers have not been putting on the furniture the type, grade and name of the finish used is that a great number of retailers have objected to even the name of the manufacturer on the goods. In later years, however, this practice is gradually being established and the better manufacturers are now on record as to the name and type and quality of finish used.

Mr. W. E. Martin: I believe that finish manufacturers have in several cases attempted to persuade furniture manufacturers and dealers to attach identifying tags to finished pieces. Our company has done this in connection with a complete group of wood finishing materials, including stains, fillers, sealers, topcoats, etc. We identified them by a trademark name and supplied tags for use on the furniture. There has not been too much enthusiasm for this on the part of the furniture manufacturers and we understand it is due, at least in part, to resistance from furniture dealers. Of course, it would take a nation-wide advertising campaign to make a trade name familiar to and accepted by the public. On the other hand, it would be pretty difficult to describe a finish in any other way except in general terms. To say a finish is lacquer or varnish would not mean much, because there are good and poor grades of both. No furniture manufacturer could be expected to label his finish anything else but good.

Mr. W. S. Robertson: There are several finishing material manufacturers who supply identifying tags or seals to be attached by the furniture manufacturer. These tags or seals state that the finish on the furniture is either lacquer or a low-bake synthetic finish, give a few simple rules for the care of the finish, and show the trade name and manufacturer of the finish.

In the past it has generally been the practice of furniture retailers to remove all identification from the furniture. Since the war this trend has decreased, as a result of aggressive advertising to the buying public by furniture manufacturers. This trend should also increase the interest in and use of tags or seals stating the type of finish used, its proper care, and identifying the trade name and the manufacturer of the finish.

The du Pont Company has promoted the use of identification and care tags or seals for many years. We are now featuring the added sales advantages of such identification in advertisements in retail trade papers, and urging the retailers to request the use of this sales help from the manufacturers. We believe that the use of identification and car tags or seals will

show a marked increase as we get further into a more competitive buyer's market.

Mr. E. J. Fishbaugh: When one buys furniture, he is buying the integrity and experience of the furniture manufacturer. For instance, several furniture companies with which I am acquainted burn their name on every piece of their case goods. They have quite accurate research facilities and capable personnel, and their purchase of a finishing material is based on careful study of the material, its schedules, etc. The results are excellent because the material will be properly applied, dried, etc.

On the other hand, another company might buy the same material, apply it without study, dry it by rule of thumb, rub it when half dry and without enough body, and stamp the name of the finish on the case. The result would be bad, and indicating the name of the finish and its manufacturer would be detrimental to the finish manufacturer; it might also be detrimental to the companies applying the same finish properly, if they publicized the name of the finish.

The name of the reliable manufacturer of furniture stamped on his goods is complete safeguard and guarantees that the finish and all else going into the finished product has been selected to uphold the quality of the completed product.

Mr. Gustave Barshefsky (The Elmendorf Corporation): Why not put instructions, as to the kind of wax to use and how to apply it, in all suits of furniture?

Mr. John H. Gividen: There is no good reason why instructions can not be put out as to how to wax and what kind of wax to use on all types of furniture. Several manufacturers of better furniture have been issuing pamphlets or leaflets or some sort of printed instructions to their customers on this subject.

Mr. R. E. Prince: Shellac and wax finishes are probably the easiest of all finishes to take care of in the home. Any good (non smear) wax can be used. On varnish and lacquer finishes care should be used in the selection of cleaning materials. Ordinarily, cleaning can be done with wax or wax cleaner, provided a minimum amount is used on the cloth, and it is wiped while still wet. Do not let wax dry on varnish finish, as it is bound to streak and is extremely hard to remove. Do not use wax on dull or dull-rubbed finishes, as it changes the effect originally desired. Soap and water or a solution of these new "soapless" soaps are ideal for cleaning dull-rubbed finished furniture.

Mr. E. J. Fishbaugh: I have watched the public for a lifetime and, while the average customer will admire the wax or one-coat finish, he will pass it by and buy a full-body finish. Manufacturers would greatly prefer to make the open-pore finish but can't sell it.

Mr. Burdett Green (American Walnut Manufacturers' Association): What is a good method of determining the public's desires regarding color, tone, style, etc.?

Mr. John H. Gividen: There are several good methods of finding what the people want in this regard. One is by the spot questionnaire, similar to the Gallup Poll, in which an interrogator questions various people with whom he comes in contact, but not according to any prearranged plan. Another method is by direct questionnaire sent to people whose names are taken from city directories, telephone directories, and other records generally available to the public. Probably the best method is watching the trend of sales from month to month and year to year.

Mr. R. I. Quigley: It is often difficult to predict what new styling and color in furniture is going to catch the fancy of the public. The furniture manufacturer, with the cooperation of his designer, finishing materials supplier, and other advisors, in seeking to develop new lines which will be pleasing brings out new styles. Sometimes these represent a somewhat radical change from the usual. Sometimes one of these new productions "clicks" and has instant appeal. It is then usually copied by other manufacturers and a new trend has been started.

I know of only two ways to predict a growing trend in furniture styling and color. One plan would be to canvas the public, probably through a consulting agency which gets the information by ringing door bells. This has been done, but would be too expensive as a usual procedure. The other plan, which is generally followed, would be to consult regularly with furniture buyers of various retail establish-

ments who are in close contact with the buying public.

Mr. Henry Draper (Home Outfitters, Inc.) Are the furniture manufacturers trying to use the best finish that can be obtained?

Mr. John H. Givideu: I would say that the furniture manufacturers of the better grades of furniture are trying to use the best finish they can get. They are doing this because the finish on furniture is the source of most complaints. Because of recent changes in the type of furniture finish, they might not always be sure that they are using the best obtainable, but they are being sincere in their efforts.

Mr. F. H. Thomas: We believe that most furniture manufacturers are trying to use the best finish they can obtain that will still fit their requirements for speed and facility in finishing. Finishes are constantly being improved and the more progressive manufacturers are rearranging their finishing schedules to use these better materials.

Mr. W. S. Robertson: Most furniture manufacturers cannot afford to maintain laboratories for testing the quality of the finish they use. While they do conduct a few simple tests, they must depend largely on their finish supplier to give them the best possible finish for their particular requirements. Finish manufacturers recognize this responsibility. They are continually working on the development of new and improved products and, with the keen competition in the finishing industry, furniture manufacturers are assured of being kept well informed on all improvements in quality. In this connection, it must be recognized that the actual type of furniture and its price class of times presents an economic barrier which makes it impossible for the manufacturer to use highest quality finishes.

The quality of finishes has improved since the war and even greater improvements are expected in the future, and the furniture industry will be quick to take full advantage of them.

Mr. Clark S. Richman (Singer Manufacturing Company): I should like to ask the members of this panel their opinion as to the best all-around, fast-drying filler.

Mr. R. I. Quigley: The best all-around, fast-drying, filler is one which will rub off and clean up satisfactorily, and which can be coated on the shortened drying schedule without producing filler puff or heaving, and which will show a minimum of shrinkage and a maximum of clarity in the final finish. Such a product may be formulated to contain other vehicle solids than Linseed Oil and Japan Dryer, but would be based primarily on a higher pigment to vehicle ratio than ordinary filler. In other words, it would be shorter in vehicle solids. Such a filler might require the use of slower evaporating thinners than the long-oil type of filler to make it work and clean up properly. For instance, part of the VM&P Naphtha with which filler is usually thinned would be replaced by mineral spirits or Stoddard solvent. In working such filler, we find that it usually breaks off cleaner and with less smear than the long-oil filler. However, it must be formulated very carefully, particularly in dark-colored filler, so that it will not produce a gray pore, since the short-oil fillers do not wet back as readily as the long-oil fillers when they are coated.

Our experience is that the majority of our customers have adopted the short-oil type of filler as preferable to the long-oil type, even though the filler is allowed to dry overnight before being coated.

Mr. W. S. Robertson: The du Pont Company has developed a synthetic filler which requires only 4 hours air drying or 1 hour at 130° F. before applying the top coats. This filler improves the scratch resistance or toughness of the finish and, in addition, is comparable to orthodox filler in application properties.

Mr. R. E. Prince: I am against quick-drying fillers unles they are of the synthetic type. Ordinarily they are not, but are compounded with low vehicle content to obtain a quick dry. I believe filler is the one material that should be given considerable attention by furniture manufacturers, since it is the basis of good finishes. Price should not enter into the selection of filler—quality is paramount.

Mr. F. H. Thomas: The best all-around fast-drying filler in our opinion is the so-called "Four Hour Type," which air dries in 4 hours or force dries in 1 hour at a temperature of 135°–140° F. It is made from a synthetic oil

base and the best grades have just as good clarity, adhesion and wiping properties as the best overnight dry types.

Mr. Melville B. Wells: What effect does the bake process have on the shrinking and swelling of the wood?

Mr. John H. Gividen: During the bake process for drying the finish, shrinking and swelling will not be in evidence to an objectionable degree if the heat and humidity are kept within reason. This, of course, is on the presumption that the wood was at the correct moisture content, or at least near it, when the finish was applied.

Mr. W. S. Robertson: We recommend that 30 to 35 percent relative humidity be maintained during the baking operation. We have never encountered any objectionable swelling or shrinking if the wood was properly kiln dried and if the proper humidity was maintained during the baking operation.

Mr. Carl Lundstrom (Lundstrom Laboratories, Inc.): What is a good scuff-proof finish to be used on a hardwood surface on the bases of office chairs?

Mr. W. E. Martin: As a general comment, there are tough grades and brittle grades of any type of finish, whether varnish, lacquer, or baking synthetic. Materials which are very fast hardening, free sanding and easy rubbing are likely to be short and brittle. Tougher materials in any type are slower hardening, do not sand and rub as freely. The manufacturer who wants a tough finish must sacrifice something in hardening speed and easy shop-working properties.

Mr. R. I. Quigley: Inasmuch as the finish on the bases of office chairs is not only subject to scuffing but also to detergents and cleaning compounds used in mopping floors, my suggestion for the best finish would be a heat reactive or low-bake synthetic varnish. My second choice would be lacquer.

Mr. F. H. Thomas: In our experience, the most satisfactory finish, for obtaining a scuff-proof finish on chairs, has been the following:

1. Stain (and fill if necessary) in the usual manner.
2. Apply a good, tough synthetic sealer coat (do not use lacquer sealer). This gives the best bond between wood (stain or filler) and top coats.
3. Sand smoothly.
4. Finish in either lacquer or varnish, using best quality, toughest materials.

Mr. Gustave Barshefsky: Why is furniture not finished on both sides?

Mr. John H. Gividen: The principal reason that furniture has not been finished on all sides is cost. For instance, the inside of drawer cabinets are rather inaccessible and the cost increase is such that in many cases it would not be justified, particularly on the better grades of furniture. Manufacturers of higher grades of furniture may not have a uniform practice concerning this, but rather carry out the finish process contingent on the climate, humidity, heat, etc., to which the furniture is to be exposed. However, the best practice for manufacturers is not to ship any furniture with unfinished wood either in exposed or unexposed places. Some of the reliable manufacturers are going to this practice.

Mr. Rudolph Willard (Snyder and Willard): In applying body coats such as sealer, lacquer, or varnish to such an item as a chair or a spool bed which must be finished all over anyway, there would be less waste of finish material by dipping instead of spraying. I know it is practical to dip certain stains and fillers. Is there any practical method of dipping the body coats?

Mr. R. I. Quigley: The dipping method for applying top-coat materials is being used on chairs and other types of furniture in the cheaper grades. However, furniture that is dipped will have a thinner coating at the top than at the bottom. Also, it is difficult to keep the material in the dip tank clean and at the proper viscosity and solid content unless it is checked and adjusted frequently. These are probably the reasons dipping is not used except for very low-priced furniture.

Mr. F. H. Thomas: Chairs, and bed ends to some extent, are currently being finished by the dipping process. The top coat is varnish, which has the flow and drain to give a smooth finish as free from runs as possible. Draining is directed toward one corner and toward the back side so that runs are as little in evidence as possible. It is this problem of

runs that prohibits this method from being used on fine furniture.

Mr. Rudolph Willard: The railroads have recently revised their specifications for packing furniture. In general, there are now two approved types of packing for case goods, the pressure pack and the clearance pack. The clearance pack is considerably more expensive than the pressure pack. This brings up a serious problem to the manufacturer of cheap furniture, who has used a varnish finish for low cost. It is probable that in the hot weather this summer the old-type finish will show serious printing if packed in a pressure pack. What can the makers of finish materials offer to solve this problem?

Mr. R. I. Quigley: The new railroad specifications for packing furniture have created quite a problem, particularly in use of the pressure pack. The manufacturer of cheap furniture usually wants a full, glossy finish on his product. Varnishes of the character to produce this type of finish also have the poorest print resistance. To go to the quicker, harder-drying varnishes means that sacrifice has to be made in the gloss and build. The only other answer I know of is to give the final coatings longer time to dry before packing.

Mr. W. S. Robertson: Use of the pressure pack calls for a finish which is more print resistant than varnish, and that means the need for a low-baked synthetic or lacquer. The economics are in favor of the baked synthetic finish, which will cost more than varnish but less than lacquer. There is an excellent chance that the synthetic finish, pressure packed, will return a lower unit cost than a varnish finish which would require the use of a "clearance" package. The change in finish would also carry with it the additional advantage of upgrading the quality.

In those cases where drying ovens are not available or the wood is not suitable for high-temperature drying, a system consisting of one coat of lacquer sealer and one coat of high solids lacquer could be used. This would be more expensive than the synthetic but less expensive than the usual two-coat lacquer system, and it could also be used with a pressure pack.

Mr. R. E. Prince: I would suggest the possibility of using a hot lacquer on furniture, especially on bases and chairs. This drys fast and print-proof overnight, is economical, and requires only one coat of hot lacquer over stain and filler or a glaze stain.

Lacquers applied by the hot method are usually 35 percent solids, while the ordinary furniture lacquer is applied at 21 percent solids. By virtue of heating the lacquer it can be applied in this heavy solids form, thereby obtaining practically two coats in one spray operation. It has proved, and is proving very satisfactory on chairs, table bases, and small furniture today. I would recommend this procedure for such items, since by saving on the finishing costs of these parts more money can be spent on the tops, in which case I would use a good lacquer sealer and rubbing or polishing lacquer. A complete finish would then be obtained in lacquer, which will give a print-proof finish.

INFORMAL BANQUET

Tuesday, March 23rd

7:00 P. M. **Main Dining Room**

EVENING DINNER PROGRAM

Presiding ---------- FRED W. GOTTSCHALK

Technical Director, American Lumber and Treating Company, Chicago, Ill.
(President, Forest Products Research Society)

Toastmaster ---------- GEORGE A. GARRATT

Dean, School of Forestry, Yale University, New Haven, Conn.
(Vice-President, Forest Products Research Society)

Wood Award ---------- RICHARD C. ART

Managing Editor, Wood, Chicago, Illinois

Presentation of Guests

Principal Speakers *Subject:* MILITARY RESEARCH

COLONEL CHARLES S. LAWRENCE

Commanding Officer, Quartermaster Food & Container Institute for the Armed Forces Department of the Army, Chicago, Illinois

REAR ADMIRAL PAUL F. LEE

Chief of Naval Research, Navy Department, Washington, D. C.

REAR ADMIRAL PAUL F. LEE
Chief of Naval Research, Office of Naval Research, Navy Department, Washington D. C.

Admiral Lee was destined for the Navy with his appointment to the U. S. Naval Academy in 1915. After a number of assignments aboard warships, he returned to college, receiving a degree of Master of Science at Columbia University.

His assignments included that of superintendent of machinery, Mare Island Navy Yard; duty in the Design and Construction Division, Bureau of Engineering, Navy Department, and special duty in England during 1940 and 1941. During the war years he received a Legion of Merit award for his administration of construction and maintenance for naval vessels in the Bureau of Ships. This background, plus his ability to get things done, resulted in his appointment to the position of Chief of Naval Research.

COLONEL CHARLES S. LAWRENCE
Commanding Officer, Quartermaster Food and Container Institute for the Armed Forces, Department of the Army, Chicago

Colonel Lawrence began his military career in World War I, serving in various assignments until 1941. He was named Quartermaster for the Luzon Force in the Philippines, at the time of the attack by the Japanese in 1942—his was the heartbreaking job of feeding the remnant of the Army left on Bataan until its surrender the 9th of April.

His present duties as commanding officer of the most advanced and far-reaching food and packaging research program in the United States are quite significant; he is a man who probably appreciates food much more than most of us. As a Jap prisoner for forty months and a participant of the infamous Bataan "death march," his daily ration often consisted of only one-tenth of a pound of fishheads or meat, and a little rice.

The Navy's Research Program

Rear Admiral P. F. Lee
U. S. N., Chief of Naval Research Washington, D. C.

IT IS quite unnecessary for me to stress the importance of research to such a group as this. The great technical advances which have been made in the utilization of forest products over the past years is an eloquent example of the effect of research on the welfare and prosperity of our country. I shall therefore attempt to describe to you why the Navy is so interested in research, what our policies are as regards its support, and what we are doing in this vital field.

For over two years, the United States, together with many other peace loving nations, has been striving to establish a world organization of such strength and prestige that it would be impossible for a new aggressor to arise. It is a goal for which every decent person the world over longs.

To achieve this goal we must have a strong, well-prepared America; one so powerful that, acting as a great moral force, we can back our desire for world peace with much strength that we could command the respect of any potential aggressor. I know of no other course which will permit us to reach our goal: History has clearly demonstrated that the unpreparedness of the United States and other democratic nations has been one of the major calculations of previous aggressors and has been largely responsible for two world wars in this century. The civilized world cannot survive a third.

It is my firm belief that one of the major factors in keeping the United States strong is scientific preparedness. I am convinced that the welfare and the security of the United States is, in the last analysis, dependent on our scientific strength as a nation. No one can estimate the capabilities and potentialities of retaliation possessed by a nation of great scientific strength. This strength is an insurance against war, not only through its potential threat of reprisals against aggression, but also in its great promise to alleviate and eventually remove the causes of war.

I would like to talk, therefore, on scientific preparedness and what the Navy is doing to help increase the scientific strength of the United States. I cannot make a better start than to quote from a statement made by Mr. Forrestal—a statment made almost three years ago when, as Secretary of the Navy, he launched the Navy on the course it is now following.

"Wars are fought primarily with weapons which are developed before the fighting begins," he said, "experience demonstrates that a nation at war usually does not have time to push through a new line of fundamental research and then apply that research before the outcome of the war is decided—it follows, therefore, that if a nation is to be scientifically prepared, its preparedness must be worked out in peactime."

Since Mr. Forrestal made this statement, the Navy has inaugurated the most extensive fundamental research program in the history of the United States. We are today supporting approximately 700 research projects in over 150 universities and non-profit laboratories. These projects reach into every field of basic science. They are in the hands of many of the most distinguished scientists in this country.

Before discussing this program in greater detail, I would like to return to the last war and some of the lessons we can learn from it.

The war against Germany involved us in a great scientific race. On the outcome of that race depended the outcome of the war itself. In the end we won—but a most important factor in our winning was the blunders of the German High Command. This is a point we must keep clearly in mind. All too many Americans labor under the false impression that our victory in the last war was inevitable, due to our great industrial strength. Great as was our industrial effort, it might well have failed us

had not the German High Command neglected his tremendous scientific resources at a most critical time.

Let us take the case of radar. When war broke out in September 1939, the United States, Great Britain, France, and Germany had all made significant progress in this field. This progress stemmed from the basic research of the German scientist Hertz, who proved in 1886 that radio waves were reflected from solid objects. Although the idea of using radio pulses to detect aircraft and ships seems to have occurred to scientists in America, England, France and Germany at about the same time, it was England who pushed the development of radio detection at the fastest tempo. This development proceeded so rapidly that by December 1935 the British Air Ministry decided to establish a chain of five radio locating stations on the East Coast of England. This was the first operational radar system installed anywhere in the world. Fifteen additional stations were authorized in August 1937 to complete the coverage of the East and Southeast Coasts and an uninterrupted 24-hour radar watch was begun on the North Sea approaches about Easter 1939. It was these radar stations which made it possible for the numerically inferior RAF to defeat the daylight air attacks against England, and, thereby, win the Battle of Britain. These same stations, improved as time went on, were also largely responsible for the defeat of the night bombing attacks against the British Isles.

By the time it was our turn to launch sustained bombing attacks against Germany, the Germans themselves had developed radar to a high level, but by that time the Allies had available a counter to radar known as "window". Window consists of strips of metal foil, which when released from planes confuse and clutter radar indicators. A bundle of such strips, cut to such a length that they are resonant at the frequency of the radio waves sent out by the radar transmitter, can return an echo similar to that produced by a plane. Thus the use of "window" greatly reduces the effectiveness of radar for control purposes. The fact that we had "window" to assist us in our bombing of Germany, while the Germans did not have it during their air attacks against England, was due to a German blunder. The Germans could have had this device in time for the Battle of Britain, since it was a German scientist who first discovered the phenomenon involved. It was not developed in Germany before the war because the Germans failed to realize the importance of this scientific discovery.

Another serious blunder of the Germans was in the development of a proximity fuse. Just prior to the war they were working actively in this field. However, after overrunning France and the Low Countries, they apparently decided that the war was won and stopped this important work. Had they continued it, and solved the problem as did we, our great bomber offensive against Germany would have met with such a deadly anti-aircraft fire that our losses would have been prohibitive.

This same over-optimism on the part of the Germans had serious effects in other scientific fields—serious for the Germans but fortunate for the Allies. What would have been the outcome of our bombing attacks upon Germany had they continued their early development of jet-propelled fighter planes instead of turning this effort to improve the performance of their bombers? Could we have invaded Normandy had the Germans fully developed their buzz bombs and V-2 rockets prior to June 1944? They could have had these weapons at least a year earlier than they did, had they not reduced their efforts in scientific research and drafted many of their scientific workers into the Army.

Eventually the Germans realized the mistake they had made. In December 1943 the German Navy's Commander-in-Chief, Admiral Doenitz, wrote, "For some months past the enemy has rendered the U-Boat war ineffective. He has achieved this not through superior tactics or strategy but through his superiority in the field of sciencee. It is essential to victory that we make good this disparity."

They then inaugurated a frenzied effort to make up for the time they had lost. From this effort came the snorkeling submarine—a submarine which was, and still is, far more difficult to detect and destroy than a conventional submarine. By means of the snorkel—a tube through which air can be drawn into the boat when operating at periscope depth—the sub-

marine exposes a very small area to radar detection, thus making the detection problem extremely difficult. Had this type of submarine been available to the Germans during the grim days of the Battle of the Atlantic, they well might have reduced England to a starving island and so isolated the United States as to have made it impossible for us to transport our troops to Europe.

But the greatest of all mistakes made by the Germans was their failure to utilize fully their great strength in scientific manpower. The German scientists were never brought closely enough to the real problem of war to give the kind of assistance of which they were capable. There was a lack of confidence and trust between the military and the scientists.

It was a matter of great good fortune to us and to our Allies that these conditions did exist in Germany. We must not, however, become complacent and build up the hope that should some future emergency arise, the same conditions will exist in the ranks of whoever might be our opponent.

Immediately prior to, and during, World War II there were established in this country the National Defense Research Council and the Office of Scientific Research and Development. To these organizations rallied our most distinguished scientists. Their efforts touched every phase of our conduct of the war. Their field extended from our laboratories here at home to the most active theaters of operation. They became an intimate and indispensible part of the team which brought us victory. I wish to emphasize that it was only through the combined efforts of scientists, industry and the Armed Forces that victory was won. This was the team which was essential to our survival in the last war and which is essential to our national security today.

To me, this is the major lesson we learned in the last war. If the security of the United States is to be assured, it is essential that there exist during peacetime the same close cooperation between our Armed Services, industry and scientists as existed during the war years. It is a matter of history that such a condition did not exist prior to World War II. It took the tragedy of Pearl Harbor and the threat to the very existence of our country to make us adopt a practice, which common sense should have taught us long before was essential to our security.

That science is one of the essential parts of national security has now been well recognized in the Military Establishment. Each of the three departments, Army, Navy and Air Force, has an organization charged with the conduct and coordination of research and development. While the organizational structure differs somewhat in each department the functions are substantially the same.

To effect coordination between the three departments, there had been created the Research and Development Board. This Board is composed of two members from each of the three departments and is under the chairmanship of a civilian, Dr. Vannevar Bush, the former Head of the Office of Scientific Research and Development, and a man to whom this country will forever be indebted. The Board functions through a series of committees covering the various fields, such as guided missiles, aeronautics and atomic energy. These committees are made up of two members from each of the three military departments and three civilians, with a civilian acting as Chairman. By this means it has been possible to bring into the deliberations of these committees the foremost civilian experts in each of the broad fields. This is a source of tremendous strength.

The Research and Development Board is directly under the Secretary of Defense. It has ample authority to discharge its responsibilities. While still a young organization, it has already made significant progress and will increase in prestige and usefulness as time goes on. This Board is not an operating agency in the sense that it conducts research and development. It is primarily a coordinating and planning agency. The actual conduct of research and development is the responsibility of the three departments.

The research and development programs of the Navy could better be defined as the basic research program on the one hand and the applied research and development program on the other. It is the objective of the basic research program to assist in the creation of new scientific knowledge in the physical, medical and biological sciences. The practical applica-

tion of this knowledge into new weapons, devices and techniques is the objective of the applied research and development programs.

The basic research program is conducted primarily in the university and non-profit laboratories of this country. Practically none of the projects carry a security classification. The applied research and development programs on the other hand normally carry a security classification of "confidential", "secret", or "top secret" and are conducted in the main in the industrial and governmental laboratories. It is these programs which produce the new types of planes, jet-propelled missiles, proximity fuses and the thousands of items which are required by a modern Navy.

It was the basic research program to which I referred earlier when I stated that the Navy had inaugurated the most extensive fundamental research program in the history of the United States. I should like to discuss this program in more detail.

The Navy embarked on the support of basic research in 1945, immediately after the termination of the war. There were many practical reasons for such a decision. In the first place, World War II had made an unprecedented drain on the scientific knowledge which had been accumulated during years of peacetime research studies. During the war practically all basic research stopped—the great majority of our scientists being engaged in the application of previously gained knowledge to developments of all types. The war's end found us desperately in need of new scientific knowledge, if we were to continue to advance our development programs.

The second important reason was the fact that in prewar years this country had depended very heavily on basic research conducted in Europe. The results of this research were available to us and were used by us. From them stemmed many of our most important industrial and military developments. As a result of the war, a large percentage of these European research sources are no longer available to us. It is, therefore, necessary that this country engage in basic research studies on a much greater scale than we did in prewar years. Since the Navy, the largest technical organization in the world, is absolutely dependent upon our country's scienitfic and technical strength, it is entirely fitting that we actively support programs which will increase our scientific strength as a nation.

A third reason, and to me the most important of all, is that by such a program in basic research we are continuing the close cooperation between civilian scientists and the Armed Services which existed during the war. This cooperation is a most essential part of our national security.

As I stated earlier, the Navy's program in basic research is composed of approximately 700 projects in over 150 universities and nonprofit laboratories. This program covers the physical, medical and biological sciences. Today about 2000 scientists and 2400 graduate students are involved in this work. The annual expenditure for the support of the program is approximately 18 million dollars.

The program with the universities is a cooperative one. We do not in any way attempt to force a research contract on a university. We request them to submit research proposals to us—research in fields in which their scientists are interested. Upon receipt of these proposals we determine whether or not to support the request, taking into consideration such factors as the Navy's interest in the specific field, the amount of work already being done in that field, the competence of the scientists who will participate in the project, the status of our funds, etc. If the decision is to sponsor the project, we then negotiate a contract with the university involved which requires the contractor to carry out work in a specific field. We do not make grants. Under the terms of the contract, the investigator is given a great deal of freedom to explore whatever promising trails he may come across, no matter where they may lead. He is started out in the general direction of a stated goal, but is governed by the value of things he finds in his path and may deviate quite freely in order to pursue those findings. We require the investigator to submit periodic reports to us as to the progress he is making, and at the end of his study to submit a complete report. Since practically all of the projects are unclassified, the investigators are permitted, in fact are encouraged, to publish in the various scientific journals such papers as

they may desire. We do however, expect the investigators to bring to our prompt attention any results which may involve military security or Atomic Energy Commission restricted data.

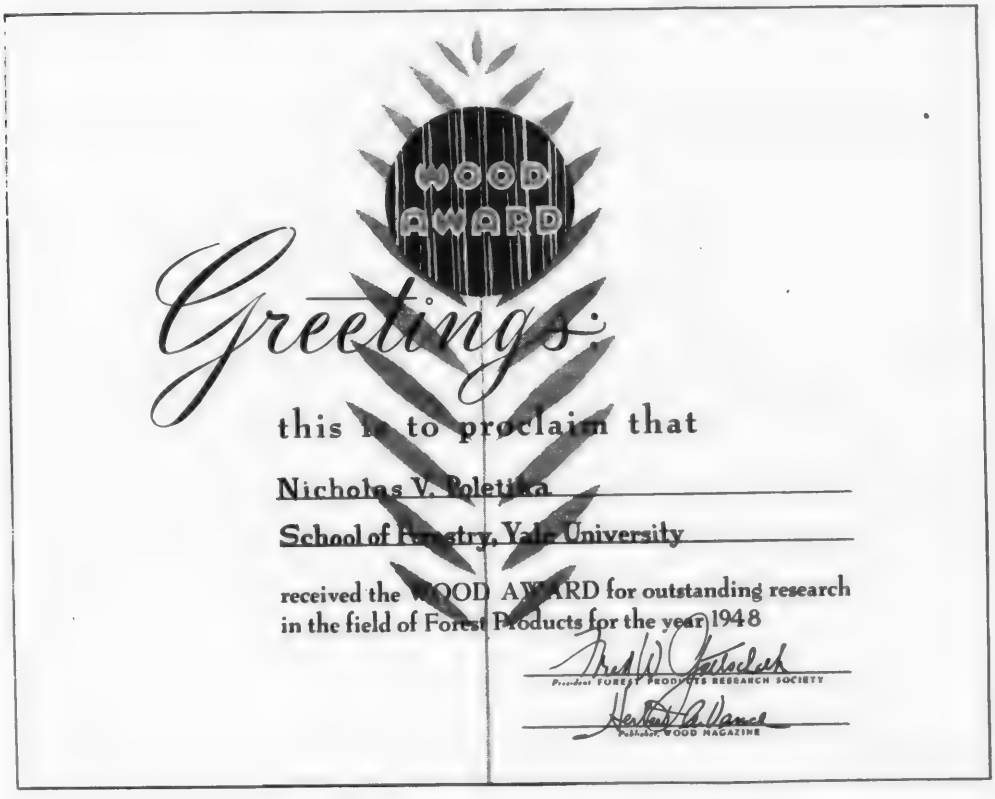
In developing this broad basic research program we have endeavored to interest scientists in fields which have in the past been neglected in this country. One example of this is cryogenics, or the physics of low temperatures. Prior to the war practically no work was done in this field in the United States. Through Navy-sponsored projects we today have some 16 laboratories equipped to work with liquid hydrogen at a temperature of minus 430 degrees Fahrenheit. Seven of these laboratories are also equipped to work with liquid helium at a temperature of minus 452 degrees Fahrenheit. Young as is this program, very interesting results are already being obtained. It has, for instance, been demonstrated that at temperatures approaching absolute zero certain materials exhibit a greatly increased capacity for conducting radio waves. Columbian nitride is a semiconductor at normal temperatures, but at very low temperatures it loses practically all of its resistance and serves very well as the superconducting element in a standard infra-red detector. This phenomenon of increased sensitivity at low temperatures has many practical applications in the Navy in connection with the design of detection equipment. It appears quite likely that we can increase the sensitivity of such equipment by factors in the order of 100 or more.

Another field in which the Navy has taken a leading part is that of basic nuclear physics. Here we are assisting a number of universities in the construction of various types of particle accelerators, as well as in the conduct of research. By so doing, we are making available to our nuclear physicists the research tools which they require to conduct advanced studies. The cost of these accelerators is such that even the most heavily endowed of our universities cannot afford to build them without assistance. This is an investment which will pay tremendous dividends in the years to come. When this accelerator program is completed, the United States will have research tools which will not only permit us to hold our present position in the field of nuclear physics, but to advance more rapidly than has been possible heretofore.

In the fields of medicine and biology extensive programs are also in progress and important results are already being achieved. For example, Navy-sponsored research has resulted in developing a new method of arterial grafting, which makes possible, for the first time, the permanent repair of injured sections of arteries without restricting blood flow. From another project has come a successful technique for the elongation of nerves, thus making possible the reinnervation of damaged limbs. An inactive plastic has been developed which permits the replacement of diseased bones. This permits early rehabilitation of the patient while the plastic material is being replaced by normal bone tissue. It now appears possible to use this material to devise an artificial joint. Progress is being made in the field of microbiology and important advances have been made in our knowledge of new antibiotics, such as streptomycin.

These are but a few examples of the results being obtained from this program in basic research. The program is still young—less than three years old, in fact. As we proceed along this path the results will be of increasing importance to the welfare of our country.

From this very brief review of the Navy's research program I hope I have given you a somewhat clearer idea of our activities, policies and programs. My talk will have been a complete failure, however, if I have not left with you my conviction that the scientific strength of our country is not only vital to our welfare but to our security as well. Scientific preparedness is one of our greatest hopes for the prevention of war and is our best insurance of victory should the catastrophy of war again descend upon us.


WOOD
AWARD
Greetings:
this is to proclaim that
Nicholas V. Poletika
School of Forestry, Yale University
received the WOOD AWARD for outstanding research
in the field of Forest Products for the year 1948
President FOREST PRODUCTS RESEARCH SOCIETY
Publisher, WOOD MAGAZINE

NICHOLAS V. POLETIKA

Following graduation from the University of Connecticut with the degree of B. S. in Forestry, Nicholas V. Poletika entered Yale University in 1941. His graduate study there was interrupted during the war for service as Research Wood Technologist and Senior Process Engineer with the Curtiss–Wright Corporation at Buffalo, New York. He returned to Yale in the fall of 1945.

After receiving the degree of Master of Forestry Poletika enrolled as a candidate for the degree of Doctor of Forestry; in the field of Wood Technology. During work on his doctorate he has served as a Research Technician at the Connecticut Agricultural Experiment Station. Poletika is a junior member of the Society of American Foresters and was recently elected to membership in Sigma Xi, national honorary science society.

Wood Award Thesis

A New Method For Studying the Elastic Behavior of Wood

Nicholas V. Poletika

Graduate Student, School of Forestry, Yale University, New Haven, Connecticut

THE accurate design of structures built with wood is complicated because wood is an orthopedic material. In contrast to an isotropic material like steel, in which strength and elastic properties are essentially equal in all directions, wood exhibits different properties in three mutually perpendicular planes corresponding to the longitudinal, tangential, and radial directions of the wood structure. The interrelationship of the elastic constants of wood in these three directions has not yet been completely determined. In recent years a number of studies of these important elastic constants have been undertaken, but much remains to be done in arriving at a precise understanding of the elastic behavior of wood. This study is a contribution toward that end.

Most previous investigations of the modulus of elasticity perpendicular to the grain of wood have been confined to studies of elasticity under compressive loads (1). In the present study, a unique method of measuring the modulus of elasticity of wood at various angles to the grain in specially prepared beams is developed. Such beams not only permit the determination of basic elastic constants, of particular significance in plywood design, but they provide an opportunity for evaluation of the effect upon beam stiffness of local cross grain when situated at various points within the span. A better understanding of these relationships is essential if wood is to attain its rightful place among engineering materials adapted to precise design work.

Basic Theory

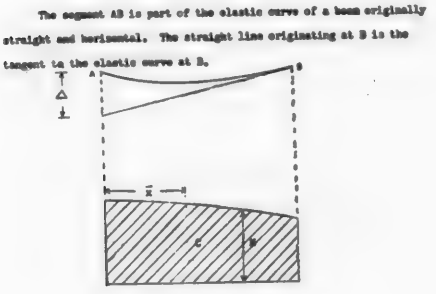
Although the principles of mechanics used in this study involving the calculation of bending moments, moments of inertia, and the drawing of bending moment diagrams are given in most books on engineering mechanics, it seems advisable to introduce a brief discussion of the basic theory involved. To the writer's knowledge, methods of analysis used in this study have not been applied previously to the investigation of wood properties.

In contrast to methods of calculating deflections of beams within the elastic range that have traditionally involved the use of integral calculus, a system, popularly known as the Area-Moment Proposition, is growing in favor because of its relative simplicity. There are two Area-Moment Propositions, of which the second lends itself more readily to the type of calculation needed in this study. The Second Area-Moment Proposition has been defined by Laurson and Cox (5) as follows:

> "The vertical displacement of point A from the tangent to the elastic curve at B equals the moment (with respect to A) of the area of the part of the bending-moment diagram between A and B, divided by EI."

The meaning of this statement may be clarified by reference to Figure 1 and the accompanying explanation.

This method of analysis, with some modification, can be applied to any statically determinate beam which contains an insert of material different from the rest of the beam. For simplicity of illustration, a hypothetical beam one inch square in cross section and with a span of 14 inches will be used. In the center of the span, a two-inch length of material B has been included. The remainder of the beam is composed of material A. The beam has a 20-pound load applied at the center and is simply supported at the ends. The modulus of elasticity of material A is assumed to be 2,000,000


The segment AB is part of the elastic curve of a beam originally straight and horizontal. The straight line originating at B is the tangent to the elastic curve at B.
A
B
Δ
x̄
C

$$\Delta = \frac{A_M \bar{x}}{EI}$$

where:

Δ = displacement of A from tangent to curve at B.

A_M = area of the bending moment diagram between A and B.

$\bar{x}$ = distance from displaced point A to the centroid C of A_M.

EI = product of the modulus of elasticity and moment of inertia of the beam.

* After Laurson and Cox.

Figure 1.—Principle of Second Area–Moment Proposition*

pounds per square inch and that of the center insert, 100,000 pounds per square inch. The steps involved in the calculation of the expected deflection follow:

1. Calculate the reaction at the supports (ten pounds in this case). Figure 2a.
2. Draw the bending moment diagram, by parts of the beam as shown in Figure 2b.
3. Convert the bending moment diagram into an M/EI diagram (Figure 2c) by dividing the M diagram by the appropriate value of EI.
4. Since in this illustration the tangent to the elastic curve is horizontal at the midpoint, the maximum deflection is at the midpoint, the maximum deflection is at the midpoint and is found by determining the displacement, from the tangent at the midpoint, of the point on the elastic curve at either support. Using either half of the M/EI diagram and dividing it into readily workable geometric shapes, the maximum deflection is calculated by adding the products obtained by multiplying each partial area of the M/EI diagram by the distance from its centroid to the reference point. As shown in the sample computation, Figure 2d, the left support has been selected as a reference point.

The preceding type of calculation can be used to determine deflections anticipated on the basis of known elastic properties or, conversely, if deflections are observed experimentally, modulus of elasticity values for various portions of the beam can be determined. The flexibility of the Second Area–Moment Proposition permits the derivation of a number of interesting results when applied to the actual beams used in these experiments.

Purpose and Scope of Study

The general purpose of this study is to investigate the relationship of modulus of elasticity parallel to the grain to the moduli at various angles to the grain by applying the principle of the Second Area–Moment Proposition to specially prepared bending specimens, and to determine the effect upon stiffness of areas of local cross grain in otherwise straight-grained beams. Specifically, the study may be considered to have four phases.

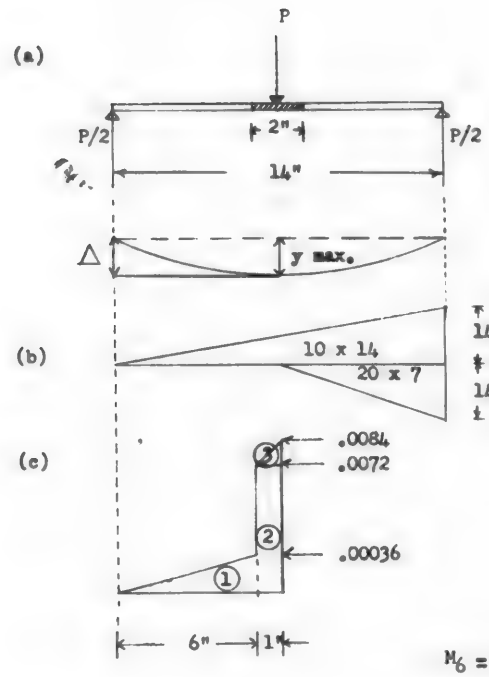
One of the principal objectives of this study is to ascertain the validity of the proposed static-bending test method of determining E_T/E_L[1] ratios by comparing test results with available data derived from compression tests.

A second phase of the study includes similar experimental determination of modulus of elasticity values at angles other than 0 and 90 degrees to the grain (called $E\theta$ for convenience). Study of $E\theta$ affords an opportunity to check the possibility of using the Hankinson formula[2] for determining moduli of elasticity at various angles to the grain from values for E_L and E_T. Calculated values of $E\theta$ obtained through the use of this formula may be compared with experimental values derived by actual testing.

A third phase of the study involves experimental determination of the relationship between E_T and E_L for yellow birch wood at

[1] E_T = modulus of elasticity perpendicular to the grain (tangential). E_L = modulus of elasticity parallel to the grain.

[2] This formula was originally presented (9) for determining the allowable compressive strength of wood loaded at an angle to the grain.



(a) From the sketch of the beam it is seen that each reaction is 10 lbs. since P = 20 lbs. The two-inch insert is located at the center. The lower diagram shows the approximate elastic curve of the beam and the point of maximum deflection. In this case Δ = y max.

(b) The Bending Moment diagram by parts is drawn from left to right for convenience.

(c) Only one-half of the M diagram needs be converted into an M/EI diagram. To get the appropriate values the following steps are performed:

$$I = \frac{bh^3}{12} = \frac{1x(1)^3}{12} = .0834 \text{ in.}^4$$

$M_6 = 60$ in.lb., $\frac{M_6}{E_A I} = \frac{60}{.0834x2,000,000} = .00036 \text{ in.}^{-1}$

$$\frac{M_6}{E_B I} = \frac{60}{.0834x100,000} = .0072 \text{ in.}^{-1}$$

$M_7 = 70$ in.lb., $\frac{M_7}{E_B I} = \frac{70}{.0834x100,000} = .0084 \text{ in.}^{-1}$

(d) The calculation of y max. is made as follows:

Δ = Ordinate of M/EI diagram x abscissa of M/EI diagram x distance to centroid.

① $.00036x\frac{1}{2}(6)x2/3(6)$ + ② $.0072x1x\left[6+\frac{1}{2}(1)\right]$ + ③ $.0012x\frac{1}{2}(1)x\left[6+2/3(1)\right] = .05512$

Since Δ = y max., the deflection = .05512 inch.

Figure 2.—Calculation of Deflection of a Hypothetical Beam of Two Materials by the Second Area–Moment Proposition Method

various moisture contents. No previous information on this relationship was available for yellow birch.

The final phase of the study includes the application of determined values for E_L, E_T, and $E\theta$ in calculating anticipated deflections of beams with inserts of various lengths and grain deviations located at various points along the span. The Second Area–Moment Proposition lends itself to this purpose.

Construction of Test Beams

It was originally decided that, to control the angle of grain deviation and length of cross-grained area, a specially prepared beam would be needed. For direct comparative purposes, areas of local cross grain in natural wood members are entirely too variable (8). A possible solution was to cut an insert of the desired grain angle and length, and to incorporate this insert in the beam by joining to it at either end two straight pieces from the same board. The difficulty of using solid wood became apparent immediately. To achieve a sufficiently strong joint between the insert and the remainder of the beam of gradually sloping scarf joint was indicated, but in a ½-inch beam a scarf-joint slope of 1 in 10 would require a five-inch length of scarf. Two such long scarfs made the calculation of length of cross grain in the insert somewhat ambiguous. To get away from excessively long scarfs, the inserts were scarfed into veneer strips, and built up to the required thickness by laminating.

Rotary-cut yellow birch veneer, 1/10 of an inch thick, was used in the fabrication of the test specimens. Each veneer sheet was examined for the true grain direction by the use of a scribe and all visible defects were eliminated from the selected sheets. Using the scribe line as a reference, pieces of veneer were cut to the desired size and grain orientation. All the components of a beam were cut from the same sheet of veneer.

A scarfing jig similar to one developed by the Forest Products Laboratory (10) was built and a hand plane was adapted for scarfing thin veneers. Details of the scarfing jig are shown in Figure 3. In addition, a simple jig for gluing of the individual scarfs and another for assembly gluing of the beams were constructed. The first involved the use of a small hot-press, while the second utilized wood cauls and C clamps.

A number of steps were involved in the fabrication of beams containing scarfed-in cross-grain inserts. The sequence of operations is presented in the following outline.

1. A piece of veneer 12 inches square was cut so that the grain was truly parallel to one of the edges.
2. The veneer was clamped into the scarfing jig and, after the blade[3] of plane was tilted to produce a scarf one inch long, a joint was cut on the full 12-inch side that was perpendicular to the grain.
3. After the scarf had been cut to a feather edge, the piece was removed from the jig and cut into two pieces, each six

[3] A back bevel was ground in the blade as recommended by the Forest Products Laboratory (10).

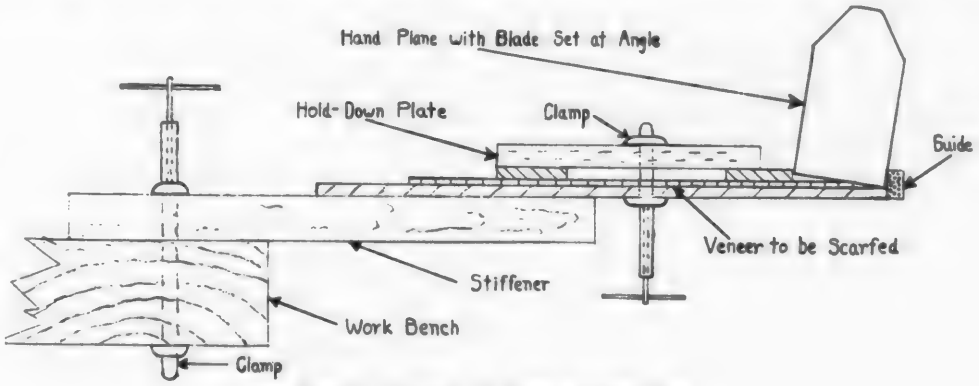


Figure 3.—Details of Veneer Scarfing Jig

inches wide and twelve inches long with the scarf on the six-inch dimension.

4. Next, a piece of veneer six inches wide and four inches long was cut with the desired grain deviation measured from the width of the piece, and a scarf was cut along this side of the piece in the same way that was used in cutting the 12-inch square.
5. The six-by-twelve piece was next tacked to a block of wood and its scarfed surface and that of the six-by-four piece were covered with a resorcinol adhesive.
6. The two coated surfaces were joined, the six-by-four piece tacked in place, and and the whole assembly cured in a small electric hot press at 200° F. for five minutes at 200 psi pressure.
7. After removal from the hot press, the cured assembly was separated from the block, and a distance which would produce the desired length of insert was measured on the shorter piece. Subsequently, a scarf was cut at this point parallel to the one which formed the joint already glued.
8. The second half of the original 12-by-12-inch square was then joined to the insert in the same way.
9. The flat sheet, consisting of three pieces of veneer scarfed together, with the shorter portion having the desired grain deviation, was next sent through a planer to remove any irregularities in the two faces and also the glue squeeze-out.
10. The planed sheet was ripped into four strips, each 1½ inches wide, and these were laminated with the same resorcinol adhesive used for bonding the scarf joints. Curing was accomplished at room temperature (approximately 75° F.), and pressure was maintained overnight by means of C clamps.
11. The glued blank was allowed to condition for a minimum of 24 hours and was then ripped into two beams each slightly over ½ inch in width. To eliminate differences in dimension resulting from sawing, most of the beams were planed to a final dimension of ½ inch. In the case of beams in which the grain of the insert formed an angle of 90° with the longitudinal axis of the beam, it was found that planing resulted in excessive tearing of the grain in the insert and these beams were finished by sanding.

In all, two beams were fabricated for each type of construction. Two insert lengths (0.2 span and 0.4 span), and five angles of the grain in the insert (0°, 15°, 45°, 75°, and 90°) were used. In certain beams where the angle differed slightly from that intended, the actual angle was used in subsequent calculations. Representative finished beams are shown in Figures 4 and 5.

Testing Procedure

The small cross-sectional dimensions of the beams necessitated slight modifications in the standard testing procedures used with small clear specimens. Since the standard span-depth ratio for small clear beams is 14 to 1, it was necessary to use a 7-inch span for the ½-inch beams. The rate of loading used, as calculated by standard formula (4) was .02-inch per minute.

The location of the insert in the span varied with the different tests depending on what effect was being investigated. In all cases, the beam was placed on the supports with the glue lines parallel to the direction of the load.

Load was applied to the specimens through a bearing head (¾-inch radius designed for a ½-inch beam. Deflections were taken at regular intervals of load (either 0.6 pound or 1.0 pound depending on the beam) and were recorded by an Ames dial which was in contact with the bottom surface of the beam. Figure 6 illustrates the test set-up used. The approximate proportional limit was calculated for each beam, and each beam was loaded to a point well below that proportional limit. Successful repetitions of each test confirmed the assumptiton that testing was limited to the elastic range. Immediately following each test, the end of a beam was cut off to form a one-inch long sample. This sample was weighed and placed in a drying oven. After the proper length of time the oven-dry weight and volume were

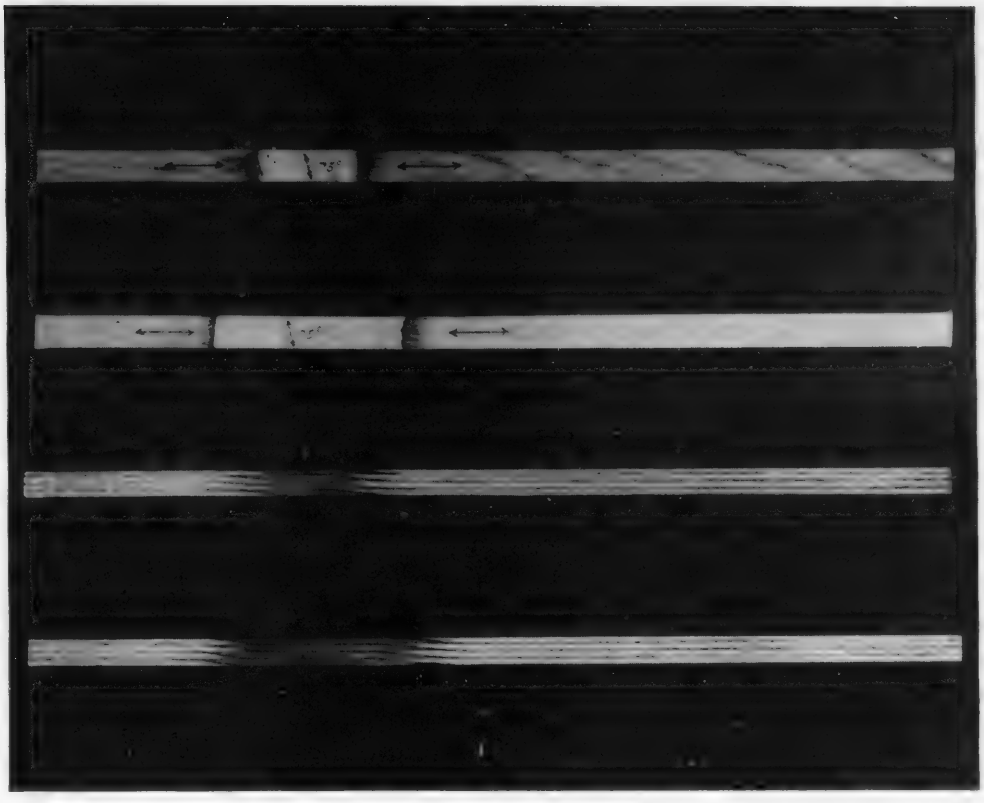


Fig. 4.—Test beams with inserts of 0.2 and 0.4 span lengths.
Upper Set: Edge View of Beams
Lower Set: Top View of Beams

determined and the moisture content and specific gravity were calculated.

Analysis and Discussion of Results

The novel construction of the test specimens necessitated a preliminary checking of the effect of the scarf on modulus of elasticity. Both types of construction (0.2 span insert and 0.4 span insert) with the grain of the insert parallel to the remainder of the beam were tested, using two beams of each type. By testing these beams with inserts at mid-span and also after they had been shifted on the supports so that the inserts were completely outside the span, it was found that the type of scarf used had no effect on the modulus of elasticity. On the basis of such proof, it was subsequently assumed that differences in the stiffness of a given beam, when tested with the insert at mid-span and also outside the span, were due solely to the type of material in the insert.

The first step in the analysis of any beam was to determine the longitudinal modulus of elasticity of the material. This was accomplished by testing a portion of the beam without an insert. The conventional modulus of elasticity formula for a rectangular beam was used:

$$E_L = \frac{P^1 L^3}{4 D bh^3} \text{---------} (6)$$

in which:

E_L = modulus of elasticity in pounds per square inch.

P^1 = a load (within the proportional limit) on the plotted deflection curve, in pounds.

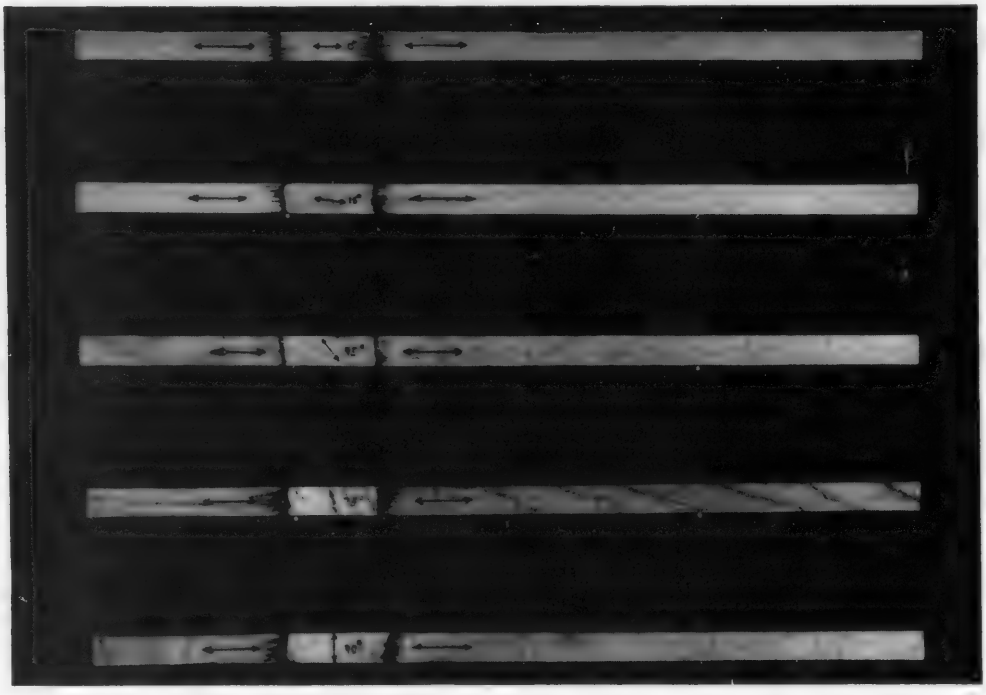


Fig. 5.—Set of test beams with cross grain inserts of 0.2 span length.
Note: Apparent differences in insert length are due to adhesive discoloration rather than variations in veneer length.

L = length of span, in inches.
D = deflection at the selected load, in inches.
b = width, in inches.
h = height, in inches.

To determine the E_T value of the material, the types of beam containing an insert with the grain direction at 90° to the rest of the beam was used. For simplicity of calculation, the center of the insert was located at mid-span. The deflection obtained at the center was used as a basis for obtaining the E_T value. By using the actual deflection thus obtained, and applying the principle of the Second Area–Moment Proposition, the value of E_T in the insert was obtained. The method of calculation is demonstrated in Figure 7. Both the 0.2 span and 0.4 span insert beams were thus analyzed. The results of these calculations are presented in Table I.

Inasmuch as extensive data for E_L are available, E_T/E_L ratios are of greater significance than absolute values of E_T. The E_T/E_L values obtained in this study should not be considered as representing average values for the species since it is known that E_T varies considerably for a given species (3). The results obtained in this study, however, are reasonably similar to the values presented in a previous investigation (3) and indicate that the Second Area–Moment principle can be used to determine the modulus of elasticity of wood at various angles to the grain.

The determination of the $E\theta$ (modulus of elasticity at an angle to the grain) was made in an identical manner, except that the grain deviation was different from the 90° used to determine the value of E_T. There are no published data with which to compare the modulus of elasticity values obtained experimentally for angles other than 0° and 90°. On the basis of known values of a property parallel and perpendicular to the grain, however, a theoretical relationship applicable to intermediate

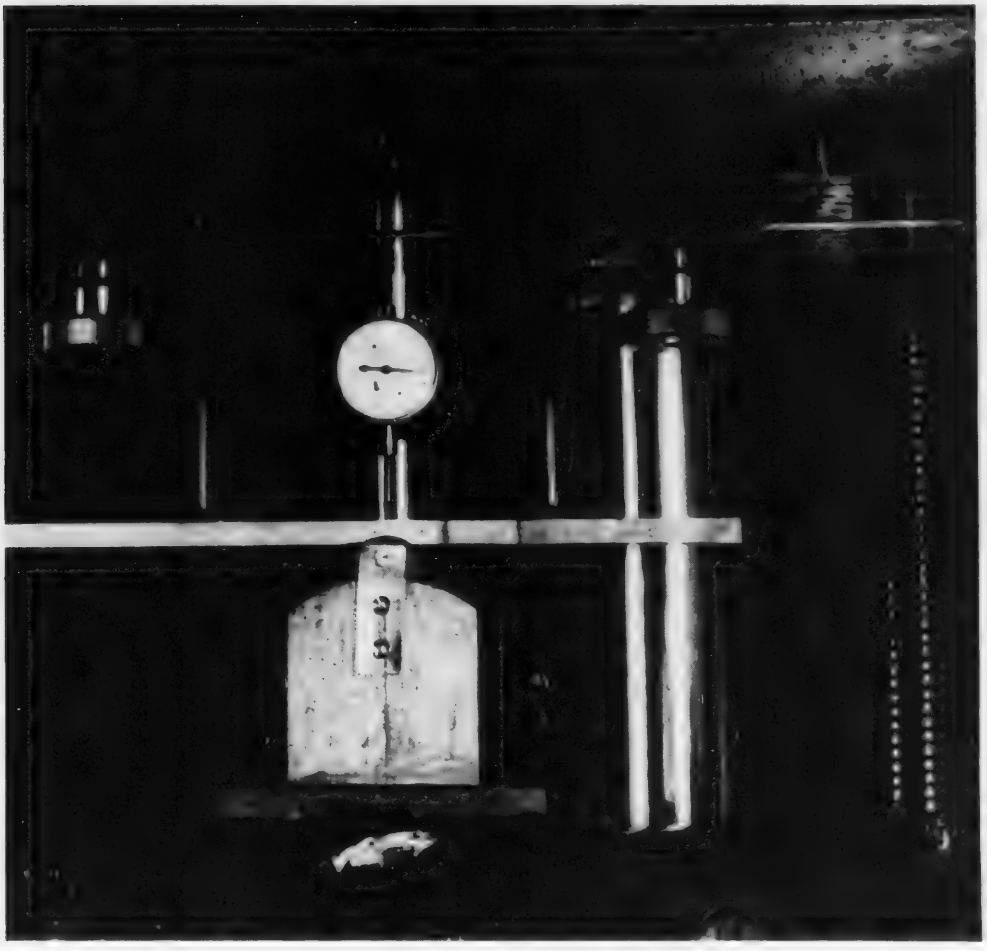
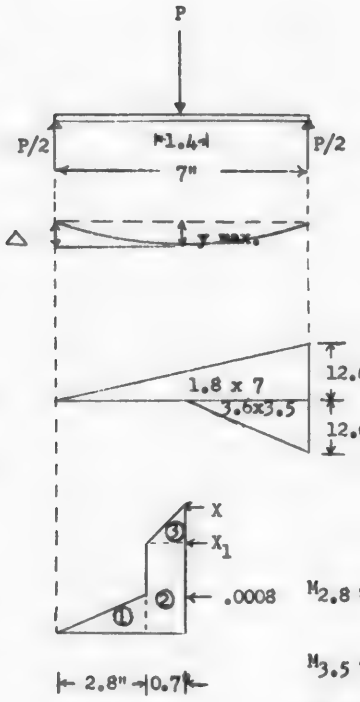


Fig. 6.—Details of set-up used in beam tests.

TABLE I—MODULUS OF ELASTICITY VALUES FOR YELLOW BIRCH PARALLEL AND PERPENDICULAR TO THE GRAIN[1]

Type of Specimen	Angle of Grain in Insert degrees	Moisture Content percent	Specific Gravity[2]	E_L p.s.i.	E_2 p.s.i.	E_2/E_L
Group A[3]						
Control[4]	----	11.9	0.64	1,300,000	---------	
Insert at Center	0	11.9	0.64	---------	1,320,000	1.01
Group B[5]						
Control	----	11.8	0.68	1,560,000	---------	
Insert at Center	0	11.8	0.68	---------	1,540,000	0.99
Average E_L/E_L	----	----	----	---------	---------	1.00
Group A						
Control	----	11.9	0.65	1,220,000	---------	
Insert at Center	90	11.9	0.65	---------	112,000	0.092
Group B						
Control	----	11.9	0.68	1,710,000	---------	
Insert at Center	90	11.9	0.68	---------	118,000	0.069
Average E_T/R_L	----	----	----	---------	---------	0.080

[1]Each value shown represents an average of two tests to two beams.
[2]Based on oven-dry weight and oven-dry volume.
[3]Group A consisted of beams in which the length of the insert was 0.2 span.
[4]The control consisted of a length of the beam where the insert was outside the span.
[5]Group B consisted of beams in which the length of the insert was 0.4 span.



(a) Selecting a load of 3.6 lbs. makes each reaction 1.8 lbs.

(b) Bending Moment diagram is drawn by parts.

(c) M/EI diagram values computed as follows:

$I = \frac{bh^3}{12} = \frac{.440x(.521)^3}{12} = .00521 \text{ in.}^4$

$M_{2.8} = 5.04$ in.lb., $\frac{M_{2.8}}{E_T I} = \frac{5.04}{1,220,000x.00521} = .0008 \text{ in.}^{-1}$

$M_{3.5} = 6.30$ in.lb., $\frac{M_{3.5}}{E_T I} = \frac{6.30}{E_T x.00521} = X$

By the slope-intercept form of the equation of a straight line, $X_1 = X - (\frac{X}{3.5} \times 0.7)$.

(d) Computation of E_T.

.0236 (actual deflection at test) = $\sum$ ① + ② + ③

① $.0008x\frac{1}{2}(2.8)x2/3(2.8) +$ ② $X - (\frac{X}{3.5} \times 0.7)x0.7\left[2.8+\frac{1}{2}(0.7)\right] +$

③ $X - \left[X - (\frac{X}{3.5} \times 0.7)\right]x0.35x\left[2.8+2/3(0.7)\right]$

$= .00209 + 1.76X + .23X$

$1.99X = .0215$

$X = .0108$

Substituting into $M/E_T I$ expression:

$.0108 = \frac{6.30}{E_T x.00521}$

$E_T = 112{,}000$ p.s.i.

Figure 7.—Calculation of E_{90} (E_T) by Second Area-Moment Proposition Based on Actual Deflection

angles may be shown by the Hankinson formula. As previously mentioned, use of the Hankinson formula in the past has been restricted to the computation of stresses at an angle to grain under compressive loads. The Hankinson formula, developed by the Engineering Division, Air Service of the United States Army (9), is expressed as follows:

$$N = \frac{P\,Q}{P \sin^2 \theta + Q \cos^2 \theta}$$

in which, according to the original significance,

N = allowable unit stress on the inclined surface.

P = unit stress in compression parallel to the grain.

Q = unit stress in compression perpendicular to the grain.

θ = angle between direction of the load and the direction of grain.

If the above symbols were to represent moduli of elasticity values for P and Q, then the formula can be adapted for calculating the $E\theta$ value at any angle to the grain intermediate to 0 and 90 degrees. In computing $E\theta$ values for the various angles of grain deviation studied, the following procedure was used. The E_L value of a particular beam was obtained by testing its control span as previously described. This served for P in the formula. The average E_T/E_L ratio, previously determined, was used as a multiplier of P to arrive at a value of Q. Solving the equation produced $E\theta$. The results of these computations based on the Hankinson formula are compared with the $E\theta$ obtained by test in Figure 8. The close similarity of the two curves in Figure 8, indicates that apparently Hankinson's formula can be used to determine with reasonable accuracy the modulus of elasticity at an intermediate angle to the grain when values for E_L and E_T are known.

The interrelationship between E_T and changes in moisture content has been studied for a few species (2, 7) but it has apparently not been investigated for yellow birch. To check the effect of moisture content on modulus of elasticity the same beams used previously were conditioned to desired moisture contents and tested. The results were analyzed by the same procedure used to determine E_L and E_T at 11.9

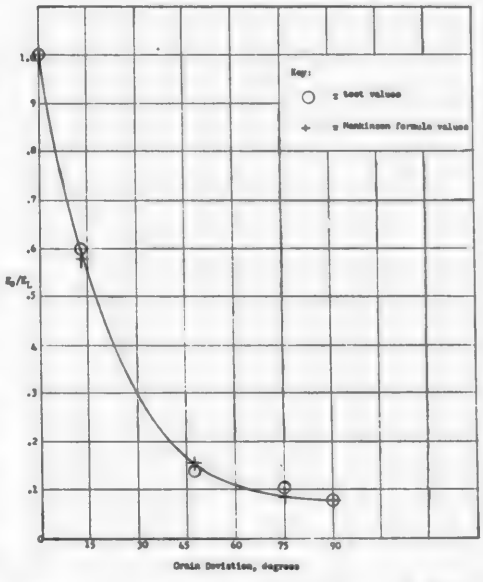


Figure 8.—Comparison of Test Values of $E\theta/E_L$ With Values Obtained by Hankinson Formula All Beams at 11.9 Percent Moisture Content

percent moisture content. It is known that the value of E_L changes logarithmically with changes in moisture content and, consequently, it may be surmised that $E\theta$ at angles other than 0° should behave in a similar manner. Taking the average E_T/E_L values presented in Table II and plotting the results on a semi-logarithmic paper (Figure 9) clearly shows that this ratio definitly changes logarithmically with changes in moisture content. The slope of the line is considerably steeper than could be expected for E_L alone. In Table II it has been shown that the material used behaves normally when logarithmic adjustments are made on the E_L values of the control. It may be concluded, therefore, that E_T changes with moisture content at a faster rate than E_L.

With these basic relationships known, it now becomes possible to study the effect of quality and quantity of local cross grain in a beam. In order to measure the maximum deflection in a beam for comparison with beams of other construction, it is necessary to know at what point on the elastic curve of the beam this point of maximum deflection occurs. In symmetrically loaded, statically determinate beams with a constant EI, the location of the point of maximum

TABLE II—EFFECT OF MOISTURE CONTENT ON MODULUS OF ELASTICITY VALUES[1]

Type of Specimen	Moisture Content percent	E_L Determined by Test p.s.i.	Calculated E_L (Basis 11.9% M.C.) p.s.i.	E_T Computed by Second Area-Moment Proposition p.s.i.	E_T/E_L
Group A[2]					
Control[3]	6.6	1,390,000	1,380,000	-------	0.114
Insert at Center	6.6	---------	---------	159,000	
Group B[4]					
Control	6.6	1,900,000	1,910,000	-------	0.086
Insert at Center	6.6	---------	---------	163,000	
Average	----	---------	---------	-------	0.100
Group A					
Control	11.9	1,220,000	---------	-------	0.092
Insert at Center	11.9	---------	---------	112,000	
Group B					
Control	11.9	1,710,000	---------	-------	0.069
Insert at Center	11.9	---------	---------	118,000	
Average	----	---------	---------	-------	0.080
Group A					
Control	18.1	1,110,000	1,170,000	-------	0.061
Insert at Center	18.1	---------	---------	67,300	
Group B					
Control	17.8	1,535,000	1,550,000	-------	0.046
Insert at Center	17.8	---------	---------	70,600	
Average	----	---------	---------	-------	0.054
Group A					
Control	27[5]	740,000	735,000	-------	0.034
Insert at Center	27	---------	---------	24,900	
Group B					
Control	27	1,270,000	1,280,000	-------	0.025
Insert at Center	27	---------	---------	31,700	
Average	----	---------	---------	-------	0.030

[1]Each value shown represents an average of two tests of each of two beams.
[2]Group A consisted of beams where the length of the insert was 0.2 span.
[3]The control consisted of a length of the beam where the insert was outside the span.
[4]Group B consisted of beams where the length of the insert was 0.4 span.
[5]Beams were soaked to about 50 percent moisture content but 27 percent was used because it is the fiber saturation point for birch (6).

deflection is relatively simple. When the EI of the beam is not uniform, but is symmetrically distributed about the center (as when the insert is at the center), then it may be shown that with center loading the maximum deflection is at mid-span. Advantage of this condition was taken in computing the moduli at various angles to the grain. When the area of cross grain is not at the center, the point of maximum deflection is not known. In order experimentally to determine this point of maximum deflection, a number of tests of beams with inserts having grain deviation of 0°, 45°, and 75° were tested. In each beam four locations of the center of the insert in the span, 1/8, 1/4, 3/8, and 1/2 span, were investigated. For each position of the insert, the half-span, containing the included insert, was subdivided into ten equal portions. A recording dial was placed under each of the increment points and a maximum deflection was recorded for a specific load. When these deflections were plotted against position in span, it was found possible to locate the point of maximum deflection. As may be seen in Table III, the points of maximum deflection were at the center for cross grain locations at 1/2 and 1/8 span. The 1/4 and 3/8 span locations caused the point of maximum deflection to fall away from the center.

The maximum deflection can be computed in a structural beam which has areas of local cross grain and in which the point of maximum deflection is known. To test the feasibility of the Second Area–Moment proposition as a method to be used in this type of calculation, the deflection obtained in the tested beams was checked by theory. The value of E_L used was that obtained through testing of controls, but the value of $E\theta$ was computed by the Hankinson formula. A sample calculation is presented in Figure 10. As may be seen in this illustration, when the point of maximum de-

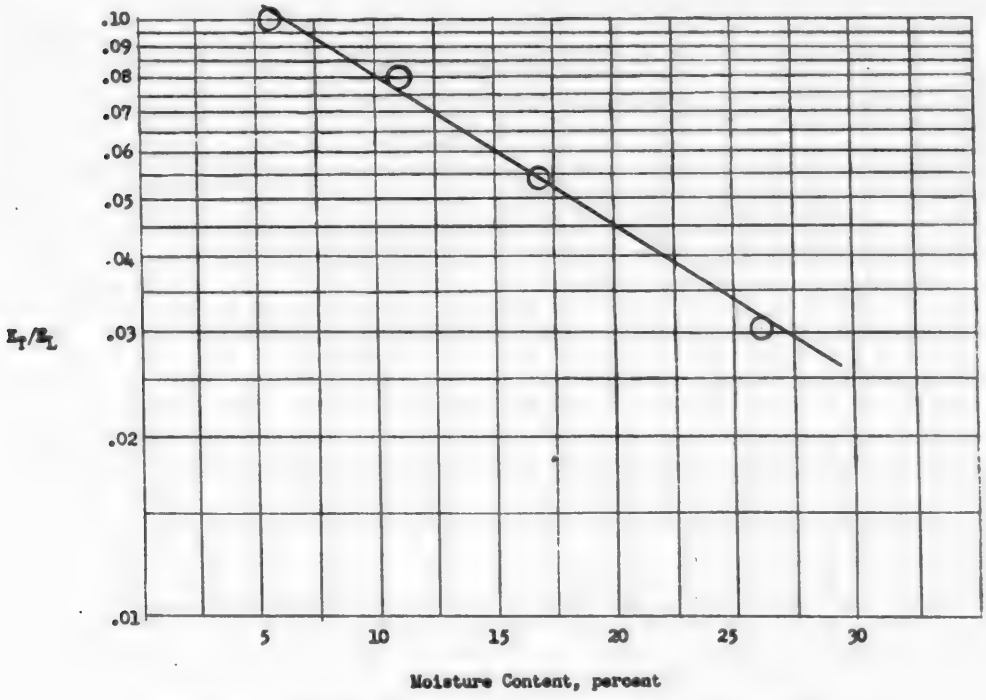


Figure. 9—Relationship of E_T/E_L in Yellow Birch to Moisture Content

flection is known only the simpler portion of the M/EI diagram to the left (or to the right) of the point need be used in the analysis, since the tangent to the elastic curve of the beam is horizontal at the point of maximum deflection. Test results and theoretical computations are compared in Table III. It is evident from the table that the theoretical and actual deflections are very similar, indicating that the method of calculation is apparently quite reliable. Further

TABLE III—COMPARISON OF DEFLECTIONS OBTAINED BY TEST AND BY THEORETICAL ANALYSIS[1]

All beams contained an insert .2 span in length and were tested at 11.9 percent moisture content.

Grain Deviation in Insert degrees	Position of Defect in Span span	Point of Maximum Deflection inches from center	Actual Deflection[2] Determined by Test inches	Theoretical Deflection Determined by Second-Area Moment Proposition inches
0	1/6	0	.0089	-----
0	1/4	0	.0091	-----
0	3/8	0	.0092	-----
0	1/2	0	.0090	-----
47	1/6	0	.0100	.0111
47	1/4	1.05	.0125	.0133
47	3/8	0.70	.0231	.0244
47	1/2	0	.0293	.0289
75	1/6	0	.0187	.0184
75	1/4	1.05	.0210	.0200
75	3/8	0.70	.0358	.0349
75	1/2	0	.0418	.0423

[1]Each value is based on two tests of each of two beams.

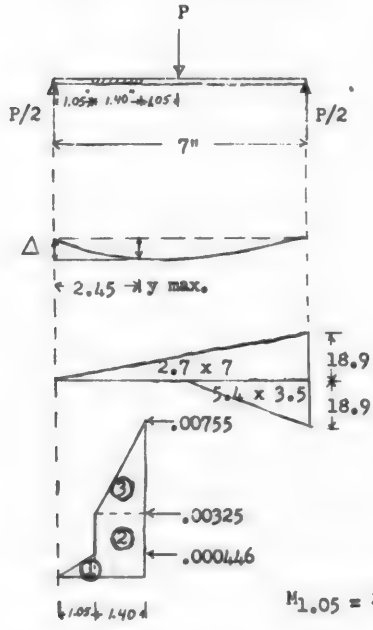
[2]The deflections should not be compared between different types of beams because of slight differences in the moments of inertia of the different beams.

work is required to extend the application of the Second Area–Moment Proposition to a beam in which the point of maximum deflection is not known.

Summary

Application of the Second Area–Moment Proposition of mechanics has made possible new and interesting studies of the elastic behavior of wood. Use of this method of analysis may initiate development of more precise design methods for wood.

Working with specially prepared beams and principles of engineering mechanics dealing with methods of computing deflections not previously applied to wood, it was found that values of modulus of elasticity at any angle to the grain can be determined. Through the use of these beams it was determined that the Hankinson formula is applicable to the calculation of modulus of elasticity values at angles to the grain other than 0 and 90 degrees. Previous application of the Hankinson formula



(a) When a load P of 5.4 lbs. is used each reaction becomes 2.7 lbs. By plotting experimental results the maximum deflection was found to occur 2.45" from the left support.

(b) Bending Moment diagram is drawn by parts.

(c) M/EI diagram values computed as follows:

$$I = \frac{bh^3}{12} = \frac{.426x(.520)^3}{12} = .0050 \text{ in.}^4$$

$M_{1.05} = 2.84$ in.lb., $\frac{M_{1.05}}{E_L I} = \frac{2.84}{1,275,000x.0050} = .000446 \text{ in.}^{-1}$

$$\frac{M_{1.05}}{E_{47°} I} = \frac{2.84}{175,000x.0050} = .00325 \text{ in.}^{-1}$$

$M_{2.45} = 6.61$ in.lb., $\frac{M_{2.45}}{E_{47°} I} = \frac{6.61}{175,000x.0050} = .00755 \text{ in.}^{-1}$

(d) Calculation of Expected Deflection

$$\Delta = ① .000446x.525x2/3(1.05) + ② .00325x1.4x\left[1.05 + \tfrac{1}{2}(1.4)\right] + ③ .00430x.7x\left[1.05 + 2/3(1.4)\right] = .01335 \text{ inch}$$

Since Δ = y max., the deflection = .01335 inch.

Figure 10.—Computation of Expected Deflection When the Area of Local Cross Grain is Not at the Center of the Span

The Beam has a .2 Span Insert with a 47° Grain Deviation and the Insert Center is Located at ¼ of the Span

was limited to allowable bearing loads in compression.

Using the method described in the previous paragraph, the relationship between modulus of elasticity perpendicular to the grain and moisture content for yellow birch was found to be logarithmic, similar to that for modulus of elasticity in the longitudinal direction. It was evident, however, that the perpendicular-to-the-grain value changes at a more rapid rate than the parallel-to-the-grain values. This relationship is very similar to that shown by published data on the two species previously investigated, Douglas-fir and Sitka spruce.

Analysis of beams with inserts of local cross grain positioned at various points in the span revealed that theoretically computed deflections check very closely with actual deflections obtained by testing.

The results of this investigation indicate that the Second Area–Moment Proposition can be advantageously used to study the fundamental elastic behavior of wood and can also be employed as a tool for use in design, when precise results are required.

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TECHNICAL SESSION VI

Wednesday, March 24, 1948, 9:00 A. M.

General Subject: Woodworking Equipment

Chairman: Jac. H. Tigelaar, Director of Research and Tests, Haskelite Manufacturing Corporation, Grand Rapids, Michigan *(North-Central Regional Board Member, FPRS)*

Recorder: Roy M. Carter, Utilization Technologist, Northeastern Forest Experiment Station, Philadelphia, Pennsylvania *(Northeast Regional Board Member elect, FPRS)*

FOREST PRODUCTS RESEARCH SOCIETY

Economics of Planning Floor Space For Woodworking Equipment

Rudolph Willard
Consulting Engineer, Ridgewood, N. J.

Floor space is a capital asset like machinery and, along with machinery and equipment, should be planned to give the best overall manufacturing efficiency. Labor costs, material costs, and production capacity are dominant. Floor space, together with other phases of the factory, should be adapted to these dominant factors.

Introduction

THIS discussion deals primarily with the economic, rather than the technical or engineering aspects of floor-space utilization in the woodworking field.

The fundamentals of mass production apply to many industries. In woodworking the fundamentals are the same as in other fields, but the emphasis is generally different. Material handling is especially important in the woodworking industry, because the materials and products are large and bulky and the individual operations are fast. Frequently, a machine operator will process more than a carload of stock a day.

Normally the success of a business is judged by the net profit, figured as an annual percentage return on invested capital. This must be kept in mind when planning investment of capital. Floor space is a capital asset like machinery, and its economics can be considered in the same way as the economics of machinery. Extra investment in floor space or machinery should be judged in relation to the savings in labor cost or the reduction in material waste which the added investment will permit, or to the increased production volume which can be obtained (if the extra volume can be sold). Sometimes the potential savings are attractive, but the additional capital is not available for investment.

Off hand, you might think that the final objective would be a shop which can produce a given product at a minimum total cost. But this is true only up to a point. It is nearly always possible to reduce direct costs by additional investment in machinery or equipment. But, if the saving does not justify the investment, it is not good economics.

Before planning floor space for a shop, it is important to define clearly what you want to accomplish. What product will you make? How much of it can you sell? What is the estimated cost in direct labor, material and overhead? Are sales steady or seasonal and, if seasonal, what maximum monthly production do you want? Are materials available as needed, or must you buy ahead and store them in order to maintain steady production?

Having determined the significant items related to the product itself, together with the maximum production capacity wanted, you must then decide upon the details of the manufacturing process. Then, having planned the manufacturing process in detail, you can start on the floor space problem. Two aspects of floor space are important, the amount in square footage, and its arrangement.

The amount of floor space should be determined for each major department. The aim should be to provide just enough space and equipment for each department, so that you have a balanced shop. Many shops have a definite production bottleneck in one department, such as the dry kilns. The rest of the shop could produce more if additional lumber could be seasoned. This is obviously poor economics, since the lag in drying lumber wastes some of the capital invested in other departments.

Generally it is the best economics to determine your manufacturing process for lowest direct labor and direct material costs, then provide enough space to do the job that way.

Lumber Yard

Labor cost in handling lumber can easily go sky high. Picking up and laying down lumber one board at a time is expensive. The "package" method of handling helps. As the lumber is unloaded out of the car, it is either bulk piled or stick piled on cross skids to form a stack of standard width and height. This stack can be subsequently moved either by a straddle-type power-driven lumber carrier or by a power-driven elevating fork truck. If you have a sufficient volume of lumber to handle, one of these power carriers will definitely pay off, but the yard must be laid out for the particular type of handling you choose, especially as regards aisle spaces and height of lumber stacks.

If the lumber is to be kiln dried, the "package" can be stick piled at unloading so that the height of the package is exactly one third the height of the kiln bunk. With an elevating fork truck, the packages can be stacked on the yard for air drying to any desired height. Later the fork truck can take three packages off the yard and pile one on top of the other to make a kiln bunk. In this way the lumber is handled a board at a time only once, at the time it is unloaded and stacked in the package.

If it is decided not to use power trucks on the yard, some extra handlings of lumber can still be avoided by sticking up kiln bunks on the roller kiln trucks at the point of unloading and moving these trucks to the storage yard. This, of course, will necessitate laying storage tracks in the yard. The unloading point, the storage tracks and the dry kilns will be served by one or more transfer cars which will handle the kiln trucks. These can be pushed by hand at a higher labor cost but lower investment.

Another important consideration affects yard layout. In some locations lumber from small mills can be bought much cheaper than big-mill stock, although this generally means buying a mixed grade, such as log run. Reduction in lumber waste in the rough mill will more than pay for the labor cost of segregating the lumber before yarding. At the unloading point, the upper grades should be segregated for use when cutting for clear stock, with the lower grades to be used for cutting for sound stock.

Frequently the lumber from small mills must be bought green. This requires extra yard space for air drying. The possibilities of end racking the green lumber should be considered, since it dries much faster on end racks.

In the case of hardwoods which are to be kiln dried, segregation for length and piling only one length on a kiln truck will considerably reduce checking and warping of the ends of the boards in the dry kiln. This segregation is best done at the unloading point. Home-made drop sorters, such as are common in big sawmills, provide a cheap way to segregate lumber by lengths.

If you are working with species such as poplar or white pine which dry fairly flat, it may pay to segregate the boards by widths. If your product is adapted to it, tremendous reductions in lumber waste can be accomplished by cutting each part from the right width of lumber. Sorting by widths can be done cheaply by home-made rigs, such as are commonly seen around pine or fir sawmills.

A handy device for sorting operations is similar to the green chain at a sawmill. This is very flexible, and makes it possible to sort for grade, species, length, width or a combination of these factors.

After deciding upon desired steps among the above suggestions or others, you can then plan the arrangement of your yard space. With large production, reductions in labor cost and lumber waste generally justify considerable investment in mechanical handling equipment and in ground for yard space. By and large, it is poor economy to operate a lumber yard the hard way, without modern equipment and with inadequate or poorly arranged space.

Dry Kilns

In planning the layout of a new plant, allowance should be made for plenty of dry-kiln capacity. The total production capacity of old shops is limited by kiln capacity more often than by almost any other factor. Every effort should be made to avoid having the dry kilns become a production bottleneck. One good way to economize on space and investment in dry kilns is to plan on high kiln bunks. Extra height means less ground space.

Speeding up dry-kiln operation increases the lumber waste due to warping, checking and casehardening. Allow plenty of kiln capacity,

so that it will not be necessary to crowd the drying schedule.

In old plants, it is often hard to find added space suitably located for building extra kilns. Following are a few ways by which the output of existing kiln buildings may be increased:

(1) Dry the lumber longer on the yard before bringing it into the kiln.
(2) Laminate thick stock instead of making it of one piece. Thin lumber dries quicker than thick.
(3) Plane the kiln stickers to ¾ inch. This will make it possible to pile a few more layers on the kiln bunk.
(4) Use forced circulation in the kilns.
(5) Provide enough kiln-dried storage, so that the kilns may be emptied and refilled just as soon as the lumber is dry. Do not use kilns for dry storage.
(6) Use enough humidity during drying to avoid casehardening, which seriously slows drying.

Dry Storage

Provide adequate space for storage of kiln-dried lumber. It is good practice to carry ten days' supply of lumber in dry storage to allow the stock to equalize in moisture content, shrink, check, etc., before cutting. A good arrangement is to equip this space with tracks to fit the kiln bunks, served by a transfer car which also serves the kilns and the rough mill where the lumber is cut. It is desirable to have the same heat and humidity in the dry storage as in the shop; if this is not feasible, a little heat is better than none.

Rough Mill

In rough mill layouts, enough cut off and rip saws should be provided so that operators do not need to work at top speed to get the required production. The big controllable cost in a rough mill is lumber waste, not labor cost.

Lumber should enter the rough mill on kiln bunks, which are spotted on a lumber lift designed to keep the top layer of lumber always at convenient height for the first machine operator.

Provision should be made for a handy method of getting kiln stickers out of the rough mill and back to the yard.

The sequence of rough mill operations should be determined for best results in reduction of lumber waste, quality control, adequate production and low labor cost. Floor space and its arrangement should be considered after this determination.

Following are some of the questions which should be answered before laying out the rough mill:

(1) Should lumber be rough planed? If so, should it be the first operation or should it come after cutting and ripping?
(2) Should lumber be faced flat before rough planing?
(3) Should you cut first, or rip first, or run one class of stock one way and another class of stock the other?
(4) Will you glue up stock direct from a straight-line rip saw or prepare the joints on a glue jointer?
(5) Can you use a gang rip saw to advantage?
(6) How many different lengths will you cut at once?
(7) Will you put rough mill scrap through a hog?

Mechanical handling of material is easier to work out in the rough mill than in the rest of the machine room, because the route of the stock from one machine to the next is fairly constant. For glued-up stock, the glue room can be included in the integrated line. Stock can be carried from one operation to the next by belt conveyors, live rolls, loose rolls or a combination of such types of equipment. Such devices save considerable labor cost. In some cases there is little if any increase in lumber waste; in other instances the extra lumber waste is prohibitive. This factor depends on the product you are making and the material from which you cut it. Each case must be studied individually.

If the rough mill is not conveyorized, it is essential that adequate parking space be provided between operations for trucks of stock in process.

The convenient removal of edgings and other scrap from the rough mill must not be overlooked. Men work better in a neat orderly shop, and conditions should be such as to make

it easy for your foreman to do a good job of housekeeping. Do not have your men working in a brush heap.

Fast-feed, high-production machines provide more output per square foot of space and also lower labor costs than slower equipment. But they also require careful production control to achieve the desired economy.

Edge-Gluing Room

The gluing process to be used should first be determined. What type of glue will be involved? Does it need heat? If so, the glue room should be made compact for easy heating. What type of clamps are to be used? Different types require different space arrangements. Consideration should be given to the newer developments in high-frequency electric curing of glue lines. You may have the conditions where this method will pay off.

Labor cost and quality control are important in this department. There should be little material waste if stock has been properly graded and machined before coming to the glue room.

Veneer Room

This is a big subject by itself. No attempt will be made to cover it here.

Machine Room

Adequate space should be provided for material coming out of the rough mill and glue room. Stock from the glue room should be held for a period (time determined from experience) to avoid sunken joints after planing. Flow of stock out of the rough mill and glue room will probably not synchronize with the rate at which you want to run lots through the machine room. Good production control will help, but considerable space will be required to hold stock and re-group it into economical lots for machining.

In most machine rooms it is not practical to conveyorize the flow of material, because stock from a certain machine may go to any one of half dozen spots for the next operation. It is probably best to use either shop trucks or pallets with lift trucks. There is lots of room for argument as to the choice between the two types of truck, but one factor is common to both, in that considerable parking space will be needed at various convenient spots. Production has a way of not moving smoothly. Congestion and jams develop and parking spaces will be necessary, if some of the machines are not to be shut down.

Assembly

Since the machine room makes individual parts, one of the critical assembly problems is to have all parts on hand before starting a job. If a finished product has thirty parts, you cannot start assembling until the machine room has made all thirty; twenty-nine will not do any good. Consequently, it is important to have considerable space for storing parts until the last item has been made and assembly can start.

Many shops use racks for this storage, in order to conserve floor space, but this is an expensive procedure. Considerable labor is wasted putting parts into racks and taking them out again. Furthermore, each time parts are handled they are subject to being dented, scratched, or otherwise damaged. For finished work, such as furniture, these dents and scratches must be sanded out, with a resultant waste in labor.

The ideal procedure is to leave parts on trucks, just as they left the last machine operation. However, this requires a lot of storage room. If space is critical, stake-type pallets can be used, being stacked three or four high by means of elevating fork trucks.

For the actual assembly operation, it will probably pay to work out various sub-assemblies leading to a final assembly.

There will be one process time to watch. Glue should be given time to set before the sub-assembly or assembly is further handled. This requires space but pays dividends. In certain cases this time can be sharply reduced by the use of a heat-setting glue, which is set either by high-frequency electric heat or by some more conventional form of heating.

Most assembly operations lend themselves nicely to conveyorized operation. Many manufacturers think of conveyors primarily as transportation equipment, and that is largely the case when they are not power-driven. But, if power driven, they also introduce the possibility of mechanical pace setting. This can be a

tremendous factor, if it is intelligently worked out and operated.

Before laying out the assembly department, a lot of time should be devoted to studying the possibilities of various forms of conveyors, such as belts, aprons, live rolls, overhead systems, and the like. They are all good, but generally for any one particular assembly problem there is one best conveyor solution.

In finished products, such as radio cabinets, one of the most important jobs in the assembly department is the sanding, cleaning and other preparation of the exposed surfaces for subsequent staining, filling, lacquering and other finishing operations. One good practice is to machine sand (mostly with sand belts) the exposed parts before assembly. They will then need to be handled very carefully, to avoid any marring which must again be sanded out. It is also desirable to get the parts assembled and into the finishing room quickly, to avoid any raising of the grain of the wood before the finish is applied. Ordinarily a day or two is soon enough, but do not sand parts weeks ahead of finishing. For efficient operation, the sanding department should be located between the parts storage and the assembly department.

Excess storage space should not be provided in the assembly department. Control your production. Assembling of a run should not be started until all parts are ready, and then it is desirable to "shot gun" it through. Unused storage space will only fill up with rejects, junk, and odds and ends, thus wasting the space and complicating the housekeeping.

Finishing

The controlling factor in finshing room layouts is process time. Stains, fillers, varnishes, etc., must have a certain time to dry before the next operation. Reduction of this time will only cause subsequent quality trouble and re-work cost.

Finishing is the easiest operation to conveyorize and one of the most profitable. Conditioned air can be blown through tunnels or ovens and, if a timed conveyor carries the product through the ovens, process times can be accurately controlled.

Several types of conveyors, such as rolls, aprons, and overhead, are in use. Each has its proper application.

The relative merits of dipping and spraying should be considered for each finishing coat. If it is practicable, dipping often saves a lot of finishing material without increasing the labor cost or space requirements.

Packing, Warehousing, Loading

In this department, woodwork shops are much like any other factory. The big controllable cost is that for labor, and much of this is pure transportation. The possibilities of overhead conveyors are worth checking, as is the use of fork trucks for piling stock several layers high, with or without pallets.

Space requirements depend not only on the total amount of stock to be carried, but also on the number of different items. Items should not be mixed in the same pile, in order to avoid re-handling when stock is shipped.

For loading, it will probably pay to set aside a loading space, where a truck load or carload consisting of several different items can be assembled. These can be taken out of the warehouse, set together on the loading floor, and then a whole car loaded at once. If possible, the loading space should be right on a railroad siding.

Checking a Layout

One good way to check a layout is to make a scale drawing of the space, on a scale of say ¼ inch to the foot. Using the same scale, make cardboard templates of the machines, shop trucks, piles of lumber, etc. Move these around on the drawing until you think it is what you want. Then check aisle space to make sure you have adequate clearance for truck movements. Also check the flow of each part from one operation to the next. Avoid back hauling the stock as much as possible. Try to keep it moving ahead. Also try to avoid cross hauling, which is indicated where flow lines cross each other. Templates for overhead items, such as conveyors, drying ovens, etc., can be on a different color of cardboard.

Check the production capacity of each operation, to see whether it is in balance, or whether you have bottlenecks in some operations and extra capacity in other spots.

Old Shops

Frequently it is desirable to reorganize an old shop, where the total floor space is adequate but poorly arranged. Many times an overhead conveyor will save enough actual labor cost to justify the investment, and at the same time will make some dead space usable. Overhead conveyors can go uphill and downhill from one floor to another as well as around corners into a side room. They are very flexible for crazy-shaped spaces and peculiar space arrangements. Once installed, they are very cheap to operate. Being power-driven they can frequently serve as mechanical pace setters, as well as for pure transportation.

Sometimes the installation of a few modern fast-feed, high-production machines will clear up a congested rough mill or machine room in an old shop. Frequently one modern machine will produce as much as two or three old-fashioned ones. If runs are sufficiently large, a modern double-end-tenoner, automatic shaper, or high-frequency edge-gluer will do wonders compared to obsolete equipment.

Another wonderful weapon for relieving congested floor space is a good production control system, operated by a wide-awake production clerk and with whole-hearted cooperation from foremen and superintendent. Here the personal factors of interest and cooperation are more important than the details of the system.

In many shops there is too much stock in process and it does not flow through fast enough. This is a bad space-killer. You can not make money on stock standing still in process; it must flow through. Check your shop once in a while. If you find many loads of stock with half an inch of dust on top, your stock is not flowing through the way it should.

Over-runs out of the rough mill are another space killer. They sit around unused for a long time. Try to prevent too much over-run; but if over-runs do occur, put them back into the rough mill to be re-cut for current production.

Scrap should not be allowed to accumulate in the rough mill. It should be either worked up for current production or burned up for fuel. Many well-operated rough mills set aside a space for re-working scrap. All that is needed is a cut-off saw and rip saw. Cutting tickets for short or narrow parts, or parts permitting sound defects, should be delivered to the scrap cutter. These parts should be cut out of scrap instead of fresh lumber. This scrap re-work department takes up space, but if properly operated it saves a world of lumber waste.

In considering the conveyorizing of a shop, it should be borne in mind that you will lose flexibility. If you conveyorize for one product and later change the product, you may be faced with expensive changes in conveyors.

In departments where quite a few men work, close supervision will pay off. This is easier if all men are in plain view of the foreman from one spot. But it is well not to have several people working quite close together; this promotes visiting instead of working. These are all factors in space arrangement which should be considered.

Summary

This discussion of the economics of planning floor space for woodworking equipment is summarized in the following 17 points:

1. Floor space is a capital asset like machinery.
2. The savings should be made to justify any investment in floor space.
3. The product, process, and volume of production should first be determined; the floor space then planned to suit.
4. Enough square footage should be provided to avoid production bottlenecks.
5. The floor space should be arranged for economics in labor and material cost.
6. Much labor cost is expended in picking up and laying down individual boards. Mechanization of lumber handling will reduce this cost; its effect on floor space is secondary, but must be considered.
7. Segregation of lumber requires extra space, but often saves much lumber waste in cutting up.
8. The moisture content of lumber as received affects the required yard space.
9. Height should be utilized, since vertical space is cheap. High kilns, multiple height stacking with tiering trucks, and overhead conveyors are factors in utilizing vertical spaces.

10. Conveyors serve for transportation and for mechanical pace setting.
11. Good production control reduces the requirement for floor space.
12. "In-process" storage is helpful in uniforming production flow.
13. New layouts should be checked with scale templates on a scale drawing on the available space.
14. Overhead conveyors can convert crazy floor-space arrangements into streamlined, usuable production space.
15. A modern machine can frequently replace several old-fashioned ones.
16. A scrap re-work department is helpful in the rough mill operation.
17. Conveyorized shops are less flexible than those without conveyor systems, when it comes to a change in product.

Discussion

Mr. W. K. Van Ormer (The Carborundum Company): In planning floor space for woodworking equipment and in making general layout plans for new or revised installations, it is vital to assess the situation completely, and in detail. What are all the goals we might wish to attain? Which of these would pay the biggest dividends through reduction of direct labor costs, particularly in the lumber yard, and in the assembly, finishing and packing rooms? Similarly, which of these would pay the biggest dividends through the reduction of direct material costs in the rough mill?

With respect to the flow of materials after the rough-mill operations have been completed and before the shipping-room operations are considered it is vital to give attention to the following points:

(1) If cuttings are small and dust-catching and space-consuming parts must falter through the shop, plan to design to permit a fair percentage of interchangeable parts;

(2) If rough-mill overcuts occur, get them out of the way;

(3) If one department or operation is a bottleneck, invest at least enough to provide adequate flow; and

(4) If design of the suites overloads one section of the plant, keep the plant limitations in mind at all times in designing new lines while the bottlenecks caused by the type of design are broken.

Mr. Willard: The question has been raised as to whether it is necessary to provide dry storage enough for ten days production. In many cases it is not necessary to have that much. But I prefer to allow for it because dry storage space is much cheaper than kiln space. Dry-kiln capacity is one of the commonest bottlenecks in shops cutting hardwood. With inadequate dry storage, the kilns are generally used for storing a few days after the lumber is dry. This further reduces the production output of the kilns.

It has also been suggested that storage of machined parts should be as close as possible to belt sanding and assembly. I am glad that point has been raised. The questioner and I see eye to eye on this point, but he has worded the thought more clearly than I did in my paper.

While this discussion has related to floor space, I am anxious to emphasize the thought that it is generally not the dominant factor. You don't want to let the tail wag the dog; and in my opinion, floor space is generally the tail while something else is the dog.

An old college professor of mine had the proverb that good manufacturing was the wise use of the four M's:

Men
Money
Machines
Materials

I should like to add a few thoughts on the relationship of floor space to the four M's:

Men: Men fall into two classes, management and the other men who work.

For the benefit of management, arrange the floor space for easy supervision. Avoid cross hauling and back hauling of material in production; keep in flowing ahead in a straight simple line. Arrange it to make good housekeeping easy. Many parts get lost in a messy shop and a lot of time is consumed in finding them again. Provide definite traffic aisles and

keep them open. Provide definite storage areas for work in process and use each area for the purpose intended. Your foreman can then tell at a glance how much work is ahead of the moulder.

For minimum direct labor cost in large machine rooms, it frequently pays to modify strict streamlined production flow by grouping several machines of a kind in one spot. This permits, for instance, a group of five shapers each operated by a low-priced semi-skilled man but all operators working under a straw boss who is head shaper man. He makes the set ups and is responsible to the foreman for the shaper work. In areas where skilled men are scarce this group method frequently solves a problem of labor supply.

Pay special attention to indirect labor operations, such as patching, moving materials, cleaning up the shop, etc. Many shops get low direct labor costs but their indirect labor go out of control. Floor space is generally a minor factor here, it is more often a matter of supervision.

Money: Big money is cheap. Where capital is available invest a lot of it but invest it wisely. Mechanize freely to save man hours. Fight for minimum cost per unit of production in order to show the most profit per sales dollar.

Little money is scarce. Where a business is under-capitalized, don't worry too much about unit cost but fight very hard for maximum turnover. A smaller profit per sales dollar is still all right if production and sales are pushed so that the capital turns over more times per year. Hold inventories small. Hold time-in-process short. In such a situation the use of dimension stock instead of rough lumber frequently speeds up turnover and permits smaller plant investment for a given volume of sales and production.

Machines: Mechanize your indirect labor operations. In most shops less money is wasted on direct labor operations than on indirect labor operations. Study the following for possible mechanization:

Transportation of material.
Disposal of scrap edgings and short blocks.
Inspection and patching.
Saw filing and knife grinding.
Firing in the boiler room.

When considering extremely high production machines, such as an automatic shaper, do not overlook the time required to make a set up. On short runs you can sometimes set up a regular shaper and have the job all run before you would get the automatic machine set up. The same situation applies to multiple borers for chair back posts and many other super-production machines.

Materials: Buy lumber which is suited to your product, right species, right grade, right sizes, right moisture condition. If you cannot buy this way, provide space at your own plant for seasoning, sorting, re-selling the part you cannot use economically.

Remember that lumber price is not as important as material cost of your product (which includes price, waste, and labor in the yard and rough mill).

The best away to utilize scrap is not to produce it in the first place.

Look into the possibilities of buying dimension stock instead of lumber. It is no panacea, but in some cases it pays.

FOREST PRODUCTS RESEARCH SOCIETY

Maintenance and Operating Practices For Tungsten Carbide Tools

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This paper presents actual applications of tungsten carbides in the woodworking industry, with particular emphasis on the care and maintenance problems inherent with the operation of such tools. It may be noted here that much of engineering, as well as the maintenance and operating practices, used in woodworking have been "borrowed" from the extensive pioneer work done by the metalworking industry. This paper also points out specific examples of unusual benefits derived from the operation of tungsten carbide tools in woodworking.

Introduction

WHAT is tungsten carbide? This is a natural question, since it has been noted that even long users of "cemented carbides" (as this metal is generally called) are totally unaware of its physical characteristics. Even today, after more than 20 years of cemented carbide manufacture, it is often referred to improperly as "carbide steel".

What Are Cemented Carbides?

The simplest definition of cemented carbides is that it is a *metal* produced through the science of powder metallurgy. It is the resultant product after several metals have been powdered, mixed, heated (sintered, as the carbide industry calls it), shaped and sintered again at heats running upwards of 2725° F. The process of making cemented carbide is illustrated, in outline form, in Figure I.

Fig. 1.—The process of making cemented carbide, in outline form.

After the first sintering, the cemented carbide can be shaped to dimensions by machining or grinding. In the case of standard shapes in production quantities, molds of the shape desired are used in the pressing operation. Final sintering, however, produces a shrinkage of 15 percent to 20 percent on each linear dimension, or approximately 40 percent in total volume, as illustrated in Figure 2. It is necessary to allow for this shrinkage in determining the final form required.

Specified quantities of tantalum, titanium and tungsten powders, mixed with carbon, are used to make different grades of cemented carbides. There is a reason for calling the product "cemented". The various hard powdered particles of tungsten carbide, etc., are held together by a suitable cementing agent—usually cobalt. Figure 3 shows the cobalt binder holding carbide particles together in a solid mass. The structure of cemented carbide can be likened

BEFORE SINTERING
AFTER SINTERING
It is interesting to note that the blanks shrink approximately
40% in volume going through the sintering furnace

Fig. 2.—Cemented carbide shrinks approximately 40 percent in volume going through the sintering furnace.

* Because of Mr. Crump's illness, this paper was presented by Mr. J. S. Gillespie, Manager, Wear Parts Engineering, Carboloy Company.

Fig. 3.—Cobalt holds the carbide particles together in a solid mass.

Fig. 4.—Moh's relative hardness scale.

to a piece of concrete from a highway. This concrete is made up of stones and gravel held together with cement. The stones and gravel are the principal "working" parts, because they resist the wear of traffic, while the cement serves mainly to hold them in place so they can do their job. In "cemented carbide" the extremely hard particles of tungsten—or tantalum—or titanium carbides, are the "working" parts and are held together by the cementing agent, cobalt.

Field of Use For Cemented Carbides

Cemented carbide approaches the hardness of diamonds (Figure 4). It is often referred to as "the hardest metal made by man", with a hardness of about 92 Rockwell "A". Here, in one metal, are such highly desirable qualities as:

High red hardness
Extreme density
High abrasion resistance
High modulus of elasticity

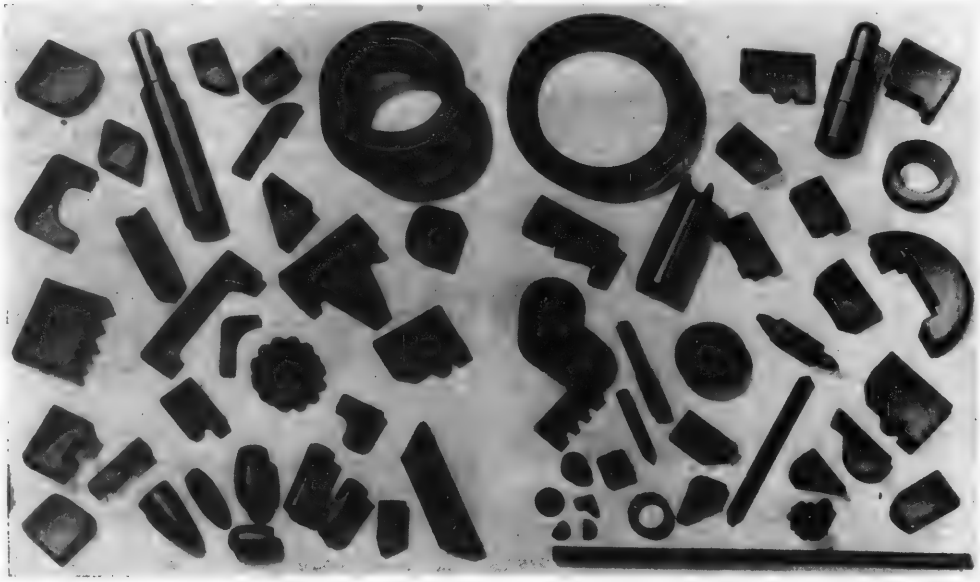


Fig. 5.—Cemented carbide can be shaped into many forms for cutting tools and wear parts.

High compressive strength
An extremely low coefficient of expansion and contraction

As a result, we find it an excellent wear-resistant material with an infinitely broad field of use in industry.

First used commercially years ago as a wire drawing die material, cemented carbides are now a primary factor in reducing production costs in both the wire-die and press-die fields. The wear-resistant qualities promote longer die life and better finish. Of course, the use of carbides in the metal working industry—for cutting tools as well as wear parts, (Figure 5)—has been a major factor in recent new machine design as a result of vastly improved methods of metal removal. Cemented carbides, highly wear-resistant, are also finding their way into other industries as wear parts, such as yarn guides in the textile industry line guides and bushings for fishing rods and reels, mattress needles, masonry drills, and paint scrapers. It has even entered the field of chemical manufacture, where its corrosion-resistant feature makes it excellent for mixer blades, valves, nozzles, etc. (See Figures 5 and 6). Because of its unusual benefits in these fields of use, it is only natural that tungsten cemented carbides should offer the same benefits and the same economies in its applications to the woodworking industry.

In recent years, the shortage of the general runs of available woods like maple, walnut, etc. for quality woodworking has caused the more extensive use of "pecan" wood. This tougher wood, harder to machine, has been made more easily manageable through the use of carbide tools. Carbide tools cut cooler, because they resist wear, stay sharp longer, and require less effort on the part of the woodworking machine operator.

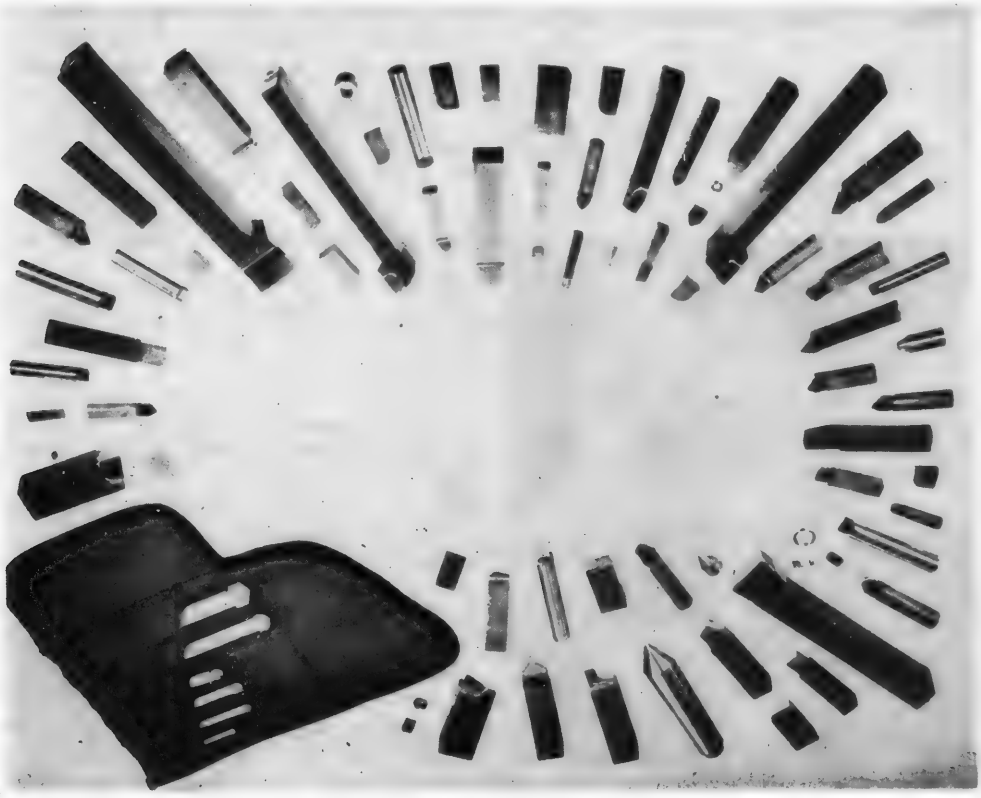


Fig. 6.—Cutting tools, centers, yarn guides, wear parts and masonry drills are made of cemented carbide.

Another important change in the woodworking industry, which has contributed greatly to the demand for carbide tools, is the advent of "urea" glue. This glue, though mixed with water and heat, will not "let go" when exposed to dampness. It therefore offers many advantages in the end product, furniture, over conventional hide glue. The conventional hide glue is a softer glue and not too harmful to steel cutters. Urea glue, however, undergoes a chemical change when subjected to the heating process, resulting in an extremely hard abrasive glue. This manifests itself in glue lines, to the extent that it is necessary to resort to more effective cutting tools. In order to offset downtime from sharpening cutters and to maintain production, tungsten cemented carbide tools were introduced.

About the Cost of Installing Cemented Carbide

Generally speaking, the investment of tungsten carbide tooling is somewhat greater than with high speed steel. This is particularly true for plants which have not been able to set up their own facilities for manufacturing and reconditioning the various types of cutters used. Plants which have established their own facilities for handling cemented carbide cutters, however, find that it costs very little more to make cemented carbide moulder or sticker heads than those of steel. Differences in cost between finished carbide tipped cutters and conventional steel cutters are due largely to two factors—initial cost of the carbide inserts used and added cost for necessary equipment, such as precision grinders for properly handling carbide tipped cutters. A typical grinder is shown in operation in Figure 7.

Fig. 7.—Precision grinders are necessary to properly grind carbide tipped cutters.

This added cost can be offset by the vastly increased production available with cemented carbide cutters versus high speed steel. Hence, it is usually only a question of time before the increased initial cost can be liquidated by improved production output. The precision finishes obtained with properly ground carbide tools often eliminates sanding and polishing operations and results in vastly improved products. The cost is further offset by savings in assembling finished parts and in the vastly increased production obtainable. Since cemented carbide cutters can be used in most instances in woodworking machines already in operation, there should be litle or no expenditure for new equipment of this type.

Cemented Carbides Under Central Control

Before proceeding into the subject of "Grinding", it should be pointed out that one of the most important phases of good "Maintenance and Operating Practice" is the establishment of a "Central Carbide Department". It has been proven in the metalworking industry and in several installations in the woodworking industry that, to obtain maximum results with greatest economies, supervision of design, brazing, application and grinding of carbide tools should be under one man. This idea is not new to the woodworking industry. Specialists in saw filing, craftsmen who know saw filing to the "nth" degree, are established personnel in every woodworking plant. With the increased use of cemented carbides, it will be easy to see the advantages gained by having control and handling of carbide tools, as well as all grinding and maintenance, under supervision of one man, in one department.

This is generally known as "centralized tool control". A typical grinding room under this system is shown in Figure 8.

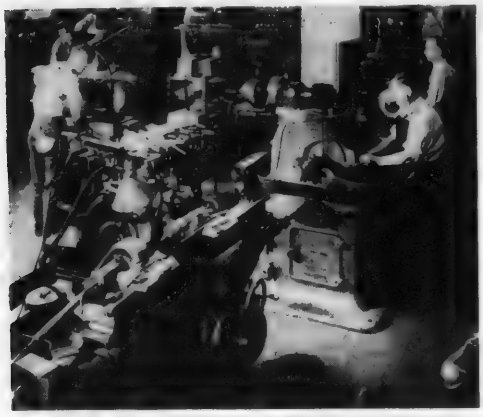


Fig. 8.—To obtain maximum results, cemented carbides should be handled under "Centralized Tool Control".

Cemented Carbides in Many Shapes

It might be well to state, at this point, that most carbide manufacturers are in a position to supply cemented tungsten carbides in almost any shape or form. Economical standard carbide blanks can be obtained for immediate use in sticker knives and jointer knives. Figure 9 shows a typical group of woodworking cutters. For special form milling and contour planing, or moulder knives, special formed blanks can be made or adapted from blanks used in metal cutting tools.

In most instances, a tough grade of cemented tungsten carbide will perform with a high degree of success in woods of all types. The manufacturers of tungsten carbide will recommend specific grades to meet the needs upon application, especially in the machining of glue lines.

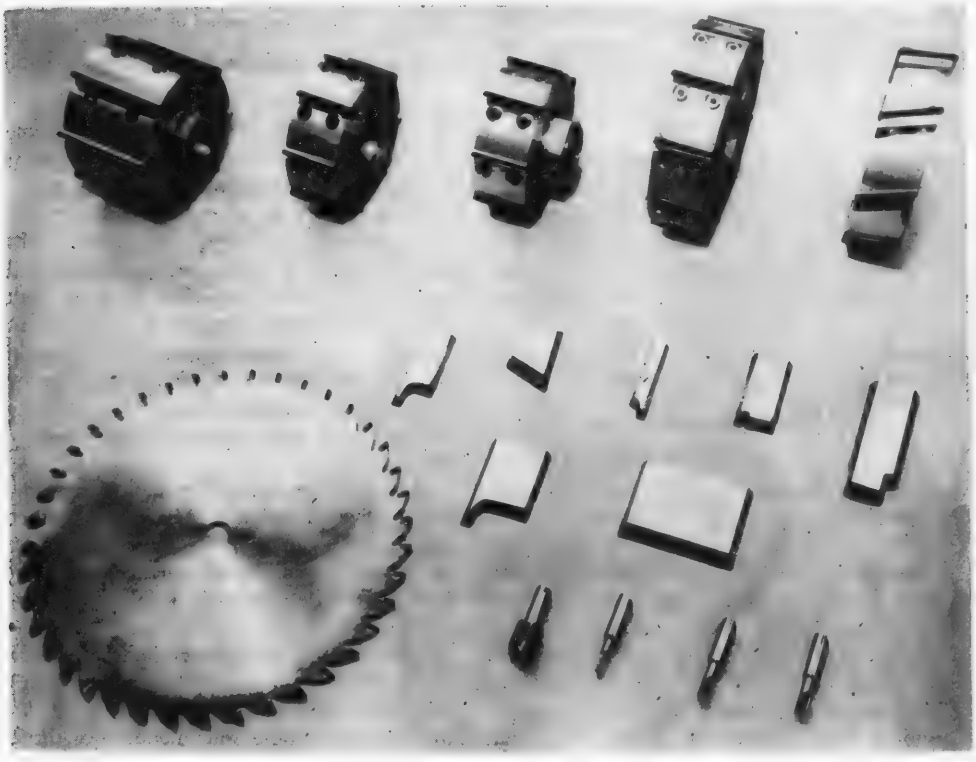


Fig. 9.—A typical group of woodworking cutters.

Fig. 10.—Proper precision grinding equipment assures best carbide grinding results.

Attachment

The various shaped cemented carbide blanks can be attached to the cutter bodies by either brazing or mechanical holding devices. There are three methdos of brazing which are now commonly used in the fabrication of carbide tipped products:

1. The use of oxygen acetylene torch.
2. With high frequency induction heater.
3. With an atmosphere controlled furnace.

The first two methods are particularly applicable to maintenance work in the average shop and they usually employ silver solder as a brazing medium. For furnace brazing copper is usually used as a brazing material.

Grinding Cemented Carbides

Since there is little basic difference in the methods of grinding tools, with or without carbides, this paper will concern itself chiefly with the necessary suggestions to obtain best results *with* cemented carbide. It is most important to use proper precision grinding equipment, similar to that shown in Figure 10, in order to obtain best grinding results, which in turn are reflected in better quality production.

Of next major importance is the proper grinding wheel. The best wheel for rough grinding the cemented carbide tip is a Silicon Carbide wheel of 80-grit grain size. Finishing the cutting edge calls for a Diamond wheel of 220–320 grit. For very fine lap finishing, a diamond dust lap is recommended. Due to the comparative "softness" of wood, it is not essential that a cutting rake be ground. However, for clearance purposes, it is recommended that the cutting edge be ground to a "knife" edge. The close-up in Figure 11 illustrates a saw tooth ground to a keen edge. This has been done with a diamond wheel.

Fig. 11.—Close-up of saw tooth.

Care and Maintenance of Carbide Tools

There is really nothing complicated or unusual about handling tungsten carbide tools. The ordinary care given any type of precision cutting tool is sufficient. Rough treatment or careless abuse will, of course, result in dulled or chipped cutting edges. Continuous running of the cutter after it has obviously dulled naturally results in imperfect work, as it does when a steel cutter is operated under the same circumstances. Should this occur with carbide tipped tools, however, the damage will be much less than with high speed or tool steel cutters, due to the greater wear-resistance qualities of the carbide.

Generally speaking, for best care of carbide tools each tool should have its own special container (Figure 12). This provides a means of obviating accidental damage through handling while the tool is in storage or in transit between the machine and the "Carbide Department". Containers or boxes are usually designed to handle one particular tool as in the case of the saw illustrated in Figure 13. Note the wooden spindle stub mounted in the box to assure secure positioning. Smaller routing bits may be placed in groups with correct sized

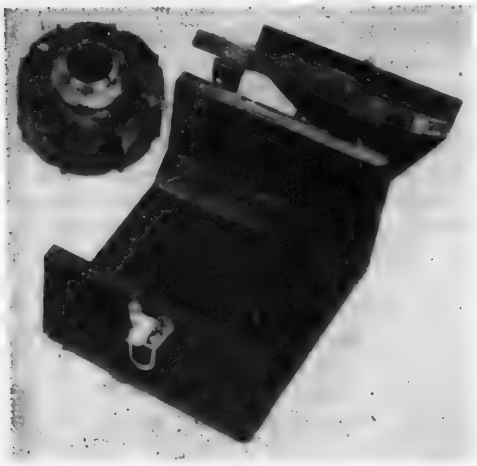


Fig. 12.—Jointer head with special container.

holes drilled to cushion the carbide-tipped cutting edges. It is well to protect the carbide as much as possible from severe bumps since the carbide cutting edge may chip, if knocked against hard objects such as the table or bed of the woodworking machine.

The Care and Maintenance of Woodworking Equipment Using Carbide Tools

Because of its ability to withstand excessive heat and wear, tungsten carbide tools can be operated much longer without grinding, and with greater table feeds than other tools. This fact does not necessitate any more than normal care of the machines on which the carbide tools are used. Most woodworking plants operate their machines at fairly high spindle speeds and existing equipment is sufficiently good for carbide tools. However, for best results spindles should run true. Spindle bearings should be accurately adjusted and sources of vibration should be removed, so that machine errors will not be transmitted to the work.

Before a moulder or sticker head is used, it should be *dynamically balanced*. Carbide blades and clamp screws also should be weighed in matching sets. This permits best use of the existing woodworking equipment and the carbide tool. An unbalanced cutter head will cut on only one or two knives, resulting in rapid wear and more trips to the grinder.

Operating Practices—General

One of the outstanding benefits derived from the application of cemented carbides in woodworking is the increased production resulting from lessened operator fatigue. Carbides cut cooler, therefore less pushing is required. Increased production is gained, for the most part, by the elimination of downtime for cutter sharpening, and through the maintained use of cemented carbide tools for long periods between grinds. It has been established repeatedly that carbide tools retain their cutting edges up to 50 times longer than steel tools.

Production costs have been further reduced as a result of often eliminating such operations as sanding and polishing. The fine accurate finish of carbide cutters permits precise matching in assembly. The "matching" of wood parts, however, precludes the use of duplicate carbide cutter heads, due to the difficulty encountered and the time consumed in matching the grinding of cemented carbide sticker and moulder knives.

Most woodworking plants will benefit by obtaining a local source of supply for carbides, a tool manufacturer who can also take care of

Fig. 13.—This 14-inch carbide tipped saw is held in place with a wooden spindle.

grinding. Best practice, of course, is to establish a "central carbide department" where all brazing and grinding can be done in the plant.

Operating Practices—Actual Case Histories

Since the advent of cemented carbides in the woodworking industry, there has been a great deal learned about how they work, their benefits, ease of operation and production increases. Although spindle speeds do not increase appreciably over those used with steel cutters, it has been found that production increases because the carbide tools can operate longer between grinds. Carbide moulder and sticker knives, for flat, grooved, or formed surfaces at 6000 rpm., stay on glue line work over two months without grinding (Figure 14).

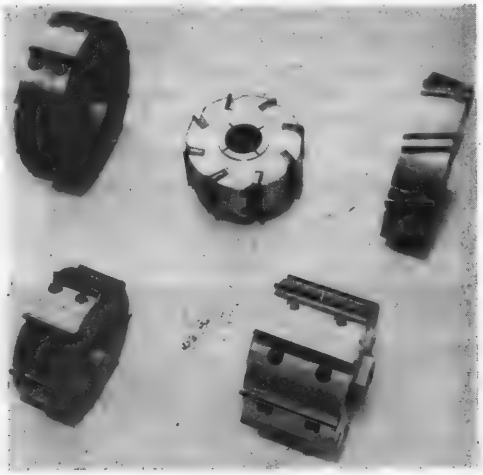


Fig. 14.—Carbide moulder and sticker knives.

Tool steel cutters last two days between grinds. On straight planing cabinet work glue lines, steel blades run from 100 to 200 linear feet, while carbides average up to 2500–3000 linear feet. One woodworking plant made a conservative estimate that cemented carbide knives on average jointer planer work, machining heavy glue lines, outlasted steel knives 50 to 1. Pecan wood, now getting widespread use, due to the shortage of other woods, is typical of the woods machineable *only* with cemented carbides. Tests (actual runs) with tool steel knives produced 800 linear feet (an hour's work) before dulling completely. Over 510,000 linear feet were run with cemented carbide knives, and still no sign of dulling.

Saws—Saws, tipped with cemented carbide (See Figure 13), are relieving production problems in several shops. One factory, for example, formerly kept three men busy grinding steel saws. It was even necessary to resort to overtime to keep up with production. Cemented carbide saws were installed and now one man, in a centralized grinding room, takes care of all saws.

As a rule, 14-inch saws usually have 36 teeth and run at about 3600 rpm., while six-inch saws with 10 teeth are operated at 7200 rpm. One plant used 22 steel saws per day, getting only 250 linear feet between grinds; after changing to carbide-tipped saws, production jumped with the saws running over two weeks without grinding.

In mounting carbide tipped saws, a light film of oil should be applied to the saw and collars near the spindle to prevent freezing. Rip-saw machine alignment should be adjusted properly. If properly set, a rip saw machine with carbide-tipped saw blades can make a glue joint as good as a glue-jointer machine.

In one plant, on general sawing work, a former steel-toothed saw was sharpened every four hours. The teeth were often damaged by stones and mineral deposits found in the wood, which was composed of maple, elm, poplar, etc. It costs about $1.00 maintenance per sharpening. Carbide-tipped saws ran four months without grinding; mineral deposits and stones had no effect on carbide and the facing was so smooth that 80 percent of the wood sawn could be joined without planing.

Router Bits—Carbide-tipped router bits (Figure 15) are enthusiastically received by woodworking plants. Running upwards of 22,000

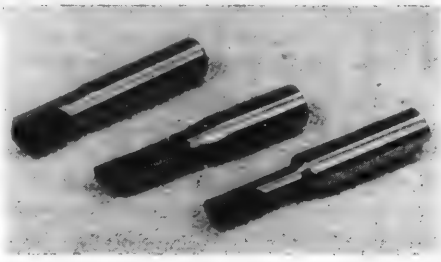


Fig. 15.—Router bits carbide-tipped).

rpm., these handy tools for general cutting and routing operations have been estimated to stay sharp up to 50 times longer than steel cutters between grinds. General practice is to use one-fluted router bits up to ½-inch diameter and two-fluted routers over ½-inch diameter. Although machine grinding is recommended, one plant reports exceptional success and time-saving by free hand grinding the router bits.

Jointer Heads—In getting into larger diameter, the heavier cutter heads, it is recommended that all knives, screws and clamp plates (steel) are dynamically balanced for best operation. An eight-bladed steel jointer head in one woodworking shop which ran only ½ hour was replaced with carbide knives (See Figure 16)

Fig. 16.—Jointer head with carbide knives.

and ran at 7000 rpm. over two months without grinding. A large desk manufacturer was faced with the problem of daily sharpening of planer heads used to plane strip edges of plywood preparatory to jointing. Eight, single-ply strips went through the machine at one time. Now, with carbide knives, the planer head finishes the entire job in 15 to 20 days, 16 hours per day, without sharpening or honing. Costs are reduced, production increased and there is practically no downtime on the job.

Moulder Heads—As more and more examples of savings with carbide knives are brought forth, the production figures take on an almost fantastic nature. Imagine a carbide tipped moulder head (Figure 17) lasting over

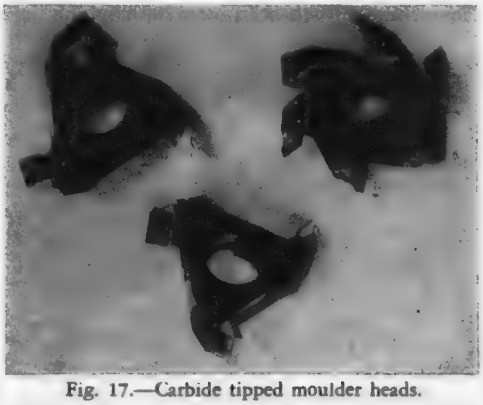


Fig. 17.—Carbide tipped moulder heads.

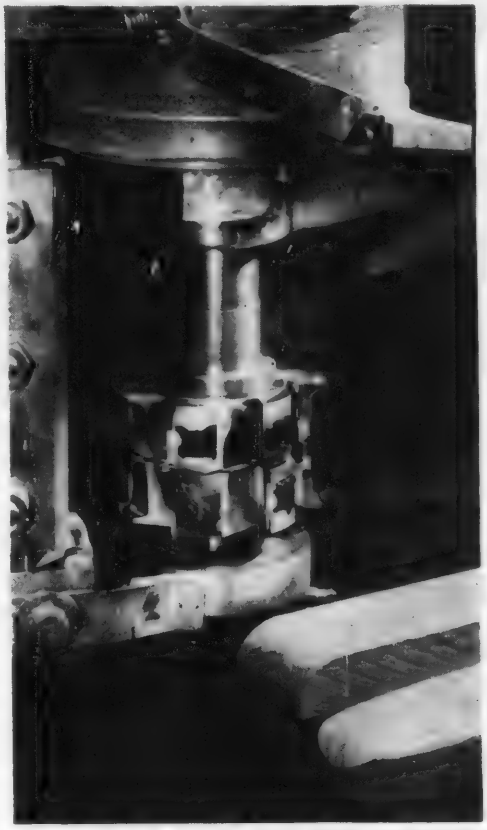


Fig. 18.—These moulder heads shape 5000 theatre seat arms per 8-hour day.

two months on continuous operation glue line work. Steel knives dulled in two days.

On theatre set arms (Figure 18), a rather intricate shaping job from rectangular maple blocks, one company estimated its annual savings from carbide heads at $10,000. This job, run at 7200 rpm., formerly netted 2000 pieces per 8-hour day with two operators. Now this job is running 5000 pieces per 8-hour day with only one operator. Depth of cut is 1½-inch maximum, with grain and against grain at a feed of about 18 feet per minute. With steel knives, the head had to be removed and sharpened every 200 pieces; with carbides, the job runs 25,000 to 30,000 pieces between sharpenings. This particular shaping job eliminated a spindle sanding operation. The theatre seat arms went from the shaper to the polishing machine. Grinding was done on the face of the cutter only and although honing is not generally necessary for woodworking tools, this carbide cutter was honed once between grinds.

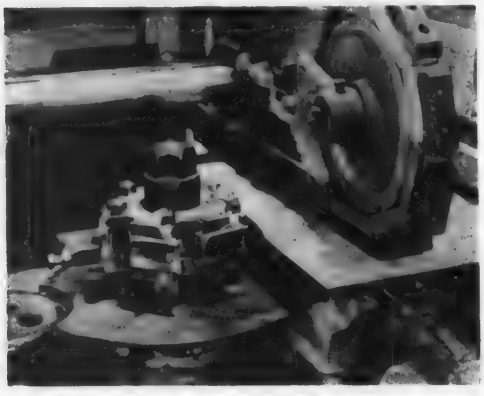


Fig. 19.—Sizing tops and rounding corners of desk tops with carbide tipped moulder heads.

Another difficult job, sizing tops and rounding corners of 7-ply ½-inch thick desk tops (Figure 19), was produced faster with carbide-tipped cutter heads. Operating at 3600 rpm. with 20 feet per minute feed, these cutters took from ⅛ to ¾-inch depth of cut, cutting with

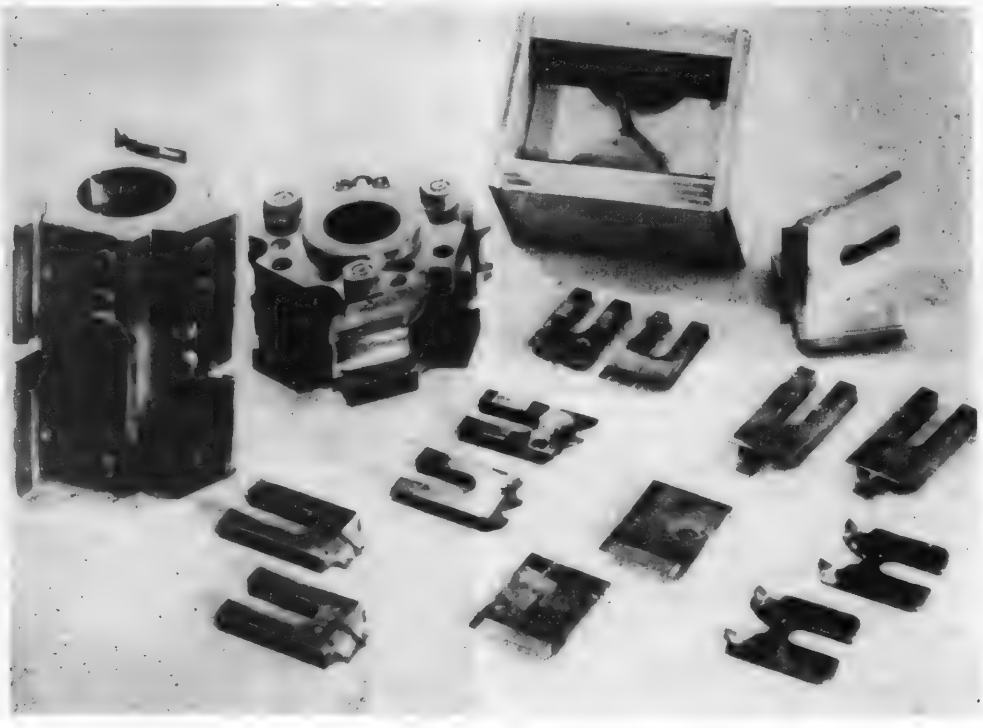


Fig. 20.—Typical carbide tipped sticker knives.

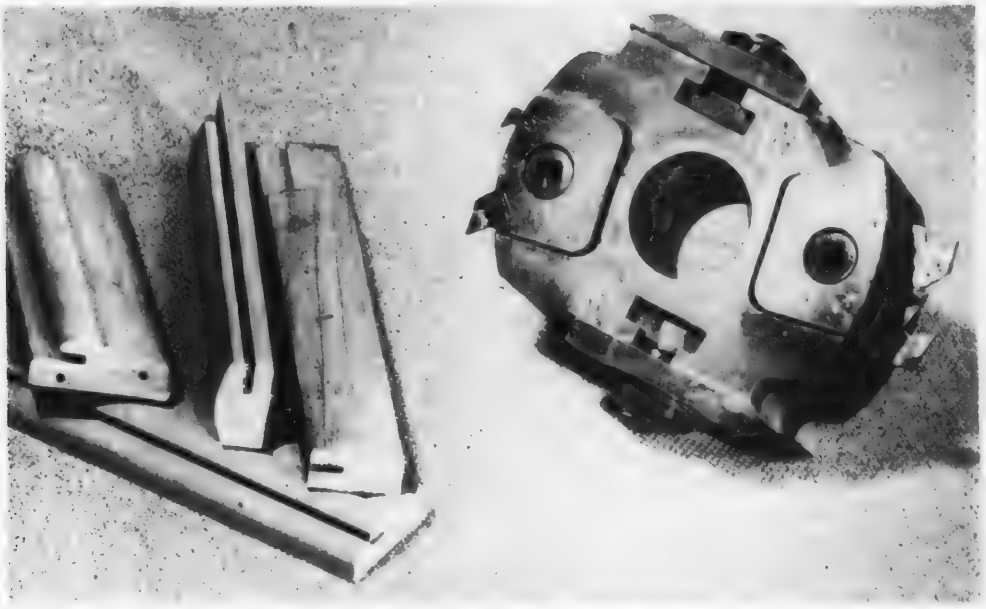


Fig. 21.—Combination knife-and-saw head.

and against the grain. Former steel cutters made 600 pieces per grind and had to be changed once every 1½ hours. Now, with carbides, 8000 to 10,000 pieces are made between grinds.

Steel sticker knives, cutting fibrous elm on a stadium-seat job, were down for over an hour for grinding and resetting two or three times a day. Carbide-tipped sticker knives (Figure 20) were put on the job and virtually eliminated downtime. The cutter head operated at 7200 rpm., 90 feet per minute with ⅛-inch depth of cut, rounding corners. Exceptionally smooth finish was obtained with a carbide-tipped tool in a combination knife-and-saw head (Figure 21). The job consisted of forming radii and cutting slots on frame strips of poplar wood. The depth of cut was ¾-inch at some points, and the head was run at 7200 rpm. with 90 feet per minute feed. Over 100,000 pieces (four foot lengths) were made between grinds. In another case, tongue and groove applications for matched pieces are now made with carbide-tipped cutters (Figure 22) which are ground once every six months.

Fig. 22.—Tongue and groove applications benefit from cemented carbide tipped cutters.

Summary

Throughout this entire paper, two major premises have been advanced with regard to "tungsten carbide tools"—

1. Cemented tungsten carbides are usually beneficial to woodworking and easily adaptable to existing woodworking equipment.
2. The unusual benefits in increased woodworking production, better finishes, greater accuracy, and reduced operating costs indicate a strong trend toward greater cemented carbide uses in the woodworking industry.

Cemented carbide tools require no greater care and maintenance than any other precision cutting tools. Their very composition, powdered metals cemented together, calls for different handling techniques. Because of their greater wear resistance, cemented carbides have infinitely longer life as a cutting medium.

Cemented carbides have opened up vast new realms of production in many other industries. There is every indication that the woodworking industry is on the threshold of a new era. Members of this Society, organized to stimulate wood research development, utilization and production, will quickly envision not only new concepts of woodworking production but also new woodworking discoveries in synthetics, treated woods, veneers, plywoods, fibrous woods and many other developments. The Society, with its broad program to encourage the quicker application of laboratory findings to industrial operations, will see in cemented tungsten carbides, a new medium which will serve as a vehicle to accelerate new discoveries in forest products.

Discussion

Mr. J. G. Hartger (Oliver Machinery Company): Our experience with carbide-tipped cutters in the woodworking field has been largely centered around circular saws which are primarily used on power-feed rip-sawing machines, and most frequently for cutting glued joints. The saws used are usually 12 or 14 inches in diameter and have from 20 to 24 teeth. The first type of saw that we furnished for this application had an alternate top bevel, and a side clearance of approximately 0.005 inch. These two factors on a power-feed rip saw presented problems in many of the applications. We found that the alternate top bevel lended itself to fracture more readily than the straight top tooth; we also found that the 0.005 inch clearance caused a pinching of the work on the side of the saw, thereby causing the saw to gum up and preventing the making of a good glue joint. From our experience and tests we find that a straight top tooth, having a side clearance of 0.020 to 0.025 inch on each side of the saw performs far more satisfactorily, and stands up much longer than the previously mentioned saw.

A few suggestions for increasing the production between grinds of these carbide-tipped saws are as follows:

(1) Clean saws of pitch each day.

(2) Make sure the full tooth projects through the work while ripping. This permits the teeth to cool and will add materially to the length of time between sharpenings.

(3) Don't try to use the saw after it becomes dull. Average recommended life is 250 hours of operation.

Mr. John W. Ripple, Jr. (The Carborundum Company): One of the major deterrents to more rapid adoption of carbide tooling in woodworking shops has been the relatively higher initial cost of carbide as compared to steel cutters. This higher price may be from a few dollars up to a figure two, three, or four times that of the equivalent steel cutter.

However, this higher price loses all meaning when ultimate cost is considered. Life of carbide cutters and length of time between regrinds frequently run to 20, 50, and 100 times that of steel. The improvement in the finish of the product from a sharp tool and the increase in production due to less "down time" for changing cutters are highly important factors which are more difficult to put on a dollar and cents basis, but which reflect themselves in the Annual Report.

Another stumbling block to carbide and a more serious one in a large number of shops is the grinding problem. Outside of the more modern places, tool-room maintenance equipment is often old and sketchy. Spindles are frequently loose and it is not uncommon to see multi-tooth cutters sharpened offhand on floor stand grinders. Carbide is not well adapted to such conditions and practices. Cutter teeth must be of the same height and contour. Angles must be accurate and cutting edges keen.

If good tool-room equipment is available, no particular problem is involved in changing over to carbide. If it is not, and management is reluctant to provide it, better results will usually be obtained during initial tests by sending cutters out for manufacture and resharpening. Many good tool shops exist in most in-

dustrial areas, some with woodworking tool experience. Their services would be valuable.

If the grinding is to be done within the shop, both silicon carbide and Diamond wheels are required on existing equipment. Silicon carbide is usually used for roughing operations and Diamonds for finishing. Silicon carbide "Green Grit" wheels for carbide differ in abrasive and makeup from aluminum oxide wheels for steel, but the action and usage are similar. Diamond wheels vary considerably from other grinding wheels. The abrasive is actual diamonds and is bonded usually in "Resinoid" plastic for cutter grinding. Wheel breakdown is very slow, due to the hardness of the abrasive itself and the tough bonding. This makes Diamond Wheels quite economical despite their high initial cost. They are a necessity in carbide cutter grinding, since they are required to produce a fine, keen, accurate edge and smooth surfaces on the blades.

The large abrasive manufacturers maintain staffs of men experienced in carbide grinding to assist users in their problems without cost. They will be glad to assist in the detailed problems and recommendations in each shop.

The objections to carbide listed above, being easily surmountable, form no real handicap to the introduction of this material to woodworking shops. The benefits outlined by Mr. Crump are so great and so common where carbide has been used that we may expect to see a relatively quick swing to this material in the woodworking field.

W. Burdette Wilkins (Consulting Engineer, Ridgewood, N. J.): On the matter of cost, Mr. Crump has used only a general comparison. I should like to see a direct comparison of costs of carbide and steel, set up to compare the factors of original cost, cost per sharpening, life of tool in finished pieces, and loss in "down time" for set up and sharpening. This comparison should be made on saw, shaper cutter, and router cutter.

Regarding the handling of cemented carbides under central control, is there any one in the business or would it be a practical set up for a knife sharpening company to take over the operation of carbide cutters in a woodworking plant and be responsible for the performance of the cutting tools on a contract basis?

Regarding attachment, grinding, and maintenance, I believe that the Carboloy Company maintains a school in Detroit which is available to those interested. Would you tell us something about that school?

Where a cutter is subject to brittle objects, such as stones, pieces of steel, etc., is there not danger of fracture that would ruin a carbide cutter, but would only cause a regrind on a steel tool?

Nothing has been said about the possibility of obtaining a keen edge on carbide tips. What process of sharpening do you recommend where a keen cutting edge is necessary, say on soft, spongy wood? Finally, what degree of included angle is practical on different tools, such as saw, planer knife, shaper, router?

Mr. Gillespie: Mr. Wilkins' question about comparative cost of carbide as against high-speed-steel tools is a tough one to answer because there are so many variables that enter into the picture. Where the amount of carbide involved is small, the original cost of a carbide-tipped tool runs very little more than the cost of a high-speed-steel tool. On multiple-tipped tools, such as saws or on large tools where the amount of carbide required is great, the cost will run anywhere from two to ten times more than high-speed-steel because the cost of carbide tips must be added. As far as the labor involved in making up the original tool is concerned, there should be very little difference. Heat-treating costs for high-speed steel are offset by brazing costs for carbide.

With proper grinding equipment, there is little difference in the cost of sharpening a carbide-tipped tool as compared with the high-speed-steel tool. An investment must be made in diamond wheels, which are rather expensive, but these wheels last such a long time when properly used that the cost for sharpening is increased practically not at all.

The life of a carbide-tipped tool in finished pieces per grind is much greater than the high-speed-steel tools. It will run anywhere from 20 to 100 times greater and we have production figures where it has been as much as 1000 times greater. As a matter of fact, on some jobs where carbides are quite satisfactory, high-speed-steel tools just won't work at all. When this increase in production is coupled with sav-

ings and "down time", carbides become very economical and practical, particularly on long-run jobs.

Mr. Wilkins asks if it is practical for a tool manufacturer to supply and regrind woodworking tools on a contract basis for numerous woodworking shops. In a community where there are numerous small shops, I believe this would be a very good way to handle this problem. The setup must be such that there will be very little lost time for shipping tools back and forth, but one shop with the proper equipment could handle the requirements of numerous woodworking shops. In larger plants, where there are many cutters to grind, our experience has been that it is much more satisfactory to set up a carbide grinding room where cutters are manufactured and reconditioned right in the plant.

Mr. Wilkins is correct in his comment that the Carboloy Company maintains a school where we train people in the fabrication and application of carbide-tipped tools. This school has been going on for some eight years and has handled several thousand men from plants all over the country. We welcome the opportunity to have your men come to our plant for training. All that is necessary is to contact one of our numerous district offices or an authorized distributor, or write a letter direct to our plant in Detroit. We make no charge for this training.

The next question is a little difficult to answer, because I am sure we all realize that it is hazardous to cut stone and nails with any woodworking tools. However, our experience has been that carbide-tipped saws and cutters are less apt to be damaged than steel cutters. There is a display right here at the show where a saw manufacturer has cut through several nails with no damage to the saw. We aren't too much concerned, because we make saws and milling cutters for cutting steel every day. We also make tipped drills for drilling in stone and masonry. If we can do this regularly, we can't see that there is too much to worry about, so far as hitting an occasional stone or nail in a piece of wood is concerned.

Next, I would like to assure Mr. Wilkins that carbide can be ground to a keen sharp edge. This is one of the advantages of carbide. Furthermore, it will maintain this edge over a long period of time. Since we are not specialists in the manufacture of various woodworking cutters, we do not feel that we should try to give definite answers in regard to the included angles, etc., that are required on the various tools for cutting various types of wood. However, we'd like to pass along comments from numerous users of carbide-tipped woodworking tools to the effect that they have found that the very acute angles usually used on steel tools are not required on carbide-tipped tools. One large user states that he never goes to a smaller included angle than 45°. You fellows who know more about this than I will have to evaluate these statements.

FOREST PRODUCTS RESEARCH SOCIETY

The Preparation of Wood Surfaces Prior to Finishing

W. K. Van Ormer

Coated Products Division, The Carborundum Company, Niagara Falls, New York

Past and present practices in preparing surfaces to receive finishing materials are covered generally. Improvements in finishing materials and the effect of their acceptance in sanding operations in relation to cabinet room and finishing room operations are noted. The uses of coated abrasive products in both the primary and final stages of the preparation of "white-wood" surfaces for the application of finishing materials are pointed out. Variations in the structure and hardness of various types of wood are considered for their effect upon the general techniques to be employed to provide proper surfaces for the application of finishing materials. Relocation and employment of sanding machinery are touched upon for the influence they exert on the subject at hand and for the effect they have upon savings in space, duplication of operations, rehandling, and hand sanding costs.

Introduction

THE preparation of wood surfaces prior to finishing presents a very different picture today than it did some years ago, and there can be no reason to expect that this picture will not continue to change in the future.

Ten years or more ago, it was relatively standard practice to make little or no adjustment of grit size of coated abrasives to allow for the variables encountered in handling various types of woods incorporating different structure characteristics and various degrees of hardness. While this may not have been completely proper, such a practice was defensible as well as practical to keep production at a high rate. However, it must be realized that such procedures placed a considerable load on those manual operations which took care of all the final stages of the preparations of those surfaces to receive the finishing materials. At that time, the use of heavy type fillers was customary and the very high costs which were common in the finishing and rub rooms were fully expected.

Since approximately 1934, new finishing room materials and practices have come into constantly broader usage. These changes in general in the type of finish produced reflected more clearly than ever the need for as good a "white-wood" surface as was possible and practical. Furthermore, the application of fewer final coats and the use of forced-drying equipment speeded up finishing room practices considerably. Not only did new rub-room techniques appear involving the use of resin-bonded coated abrasives to replace pumice so as to speed up production, but without expansion of the size of most plants, increased flow of materials to the finishing room from both the machine and cabinet rooms was an increasing possibility. Better, higher-speed planers, shapers and tenoners achieved part of the goal. Improved alloy-steel cutting elements produced better surfaces at high speed and for longer periods of time before sharpening or replacement was necessary. These improved surfaces of parts coming from the machine room assisted the normal cabinet room operations in doing a far better job in preparation for the finishing materials. A considerably different and better sanding job had to be done without an increase in the size of the cabinet room, with assembly taking place in that same area as usual. In a relative sense, it can certainly be stated that most plants have succeeded in achieving a better sanding job without an increase in space allocated for that purpose, but many of us probably have asked how this has been accomplished in a crowded area with much handling and rehandling and large amounts of space taken up with loaded and empty truck-dollies. Some plants have created a separate sanding room and established a separate cabinet assembly room, but these are in the minority. The possibilities of other approaches to this situation will be considered later.

Procedures and Recommendations

The objectives of preparing a proper white-wood surface to receive and retain good finishing materials effectively may be listed as follows:

(1) To reduce the depth of the sanding scratches after the general surface has been obtained through previous sanding operations, and

(2) To create an evenly-finished surface into which stains will penetrate as evenly as possible.

To achieve the second of the points listed above, it may be obvious that it is necessary to give due consideration to the variation in the hardness and porosity characteristics of the different woods being sanded in one plant, and to consider that different kinds of wood or different grain cuts of one kind of wood, or both, are employed every day in the manufacture of single pieces of cabinet work.

The surfaces obtained through a multiple-drum sanding operation are only primary and are not meant to be perfect. One or more belt sanding operations are expected on any parts whereon the customer will be able to see the effect of reasonable preparation of those surfaces for the finishing materials. The problem of snake marks produced on such a machine need not be of terrific concern except on those few parts on which no further sanding is needed. Snake marks have little effect on the difficulty encountered in performing the next sanding operation. Of course, snake marks are undesirable and should be reduced and/or eliminated by all possible means.

The most important characteristics, of a multiple-drum sander, however, are that it must do an effective and efficient job of the creation of a general plane or surface, in improving the surface produced in the machine room and in the making of the panels. It must do a sufficient part of this job so that subsequent operations usually involving belts can bring the finished surface to a point where the proper characteristics will be evident.

In brief, aluminum-oxide-coated abrasive papers are employed on such machines when hard woods are being sanded, when frames including hard glue and possibly nails are to be surfaced, or when a large amount of tape is to be removed. Although garnet-coated abrasive papers would soon become dull under such treatment, they are most advisable, at least on the first two drums, wherever these difficult surfacing conditions are not encountered to any great degree. In multiple-drum sanding, the trend to use abrasive papers of finer grit sizes is directly traceable to the demand for better final finishes and the desire to avoid two belt sanding operations on flat stock where one can possibly suffice. While undue effort to avoid a second belt sanding operation is often inadvisable, the use of such finer grit sizes on such machines has been rendered at least partially possible through the use of improved planers improved, glues and panel-making practices, and light-weight veneer tapes. It will probably suffice today to say that most manufacturers are employing 100-grit papers on the last drum for general work and 120-grit similarly where large quantities of drawer-bottoms are involved. In a great many instances, the formerly common use of 40-grit paper as the coarsest type has been supplanted with No. 50 or No. 60-grit, preferably the former.

From the above, it will be evident that no great change has taken place in the grit sizes employed on such machines. Analysis of the practices and findings of many manufacturers proves this to be practical. It may, therefore, be of interest to note, when we consider the next normal step on flat panels, namely flat-belt sanding, that a rather distinct and marked change has taken place over the past ten years resulting in the use of considerably finer grit sizes. These aid materially in accomplishing some of the points we have considered numerically above. Now we find 180 grit and 220 grit being employed on swirls, butts and crotches, whereas 120 and even 100 grit were in use in many plants ten to fifteen years ago. Similarly, No. 150 and 180-grit papers are being used mechanically on straight-grain veneers, etc., today, where No. 100 grit was formerly very common.

Improvement of final white-wood finished surfaces, as well as increased interest in attacking hand-sanding costs, become evident in the employment of final belt-sanding operations involving the use of No. 240-grit papers. The fact that many plants have created an intermediate cabinet-finishing room for this explicit purpose, is of further interest. At this

point, the assembled articles are belt sanded to remove clamp marks, dents, spots of glue, etc. Material improvements thereby become possible, not only in the reduction of hand-sanding costs, but also in the improvement of the appearance of the article after stains of any type have been applied. The interesting developments of the next several years should indicate the degree to which furniture manufacturers will proceed further with the prospects involved in the improvement of the final sanded finish on moldings, posts, carved legs, chair backs, and the like, as the trend continues still further towards the revealing of the true appearance of the wood incorporated in the article by eliminating dark and heavy fillers.

It is obviously interesting to the manufacturers of coated abrasive products to see the consumption of those products increased through the improvement of white-wood finishes accomplished prior to the application of stains, wash-coats, sealers, etc. It is immediately evident that this is a trend which has met with consumer acceptance in the homes of modern America, in relation to period styles as well as in modernistic furniture and radio cabinets.

From the above, it is believed that we can conclude that the changes which became possible and which have taken place in finishing room practices and procedures have reduced materially the cost per piece in the finishing room. At the same time, the amount of work to be done in the sanding and/or cabinet room has been increased. The use of belts of finer grit-size in the sanding room has surely served to reduce hand-sanding costs, but, while it would appear that this has been accomplished effectively on flat surfaces in many plants, similar procedures would appear advisable on other than flat surfaces.

It is interesting to note that relocation of sanding machinery, not only in the sanding room but in the machine room as well, has made possible savings in handling costs which more than offset the added costs for perishable materials, such as coated abrasives.

Examples of this can be found in the locating of multiple-drum sanders in the machine room close to the molders and double-end tenoners. The savings in space and handling thus made possible in the sanding room, for example, far exceed the saving in labor costs by using the "tail-man" at the tenoner to feed the multiple-drum sander. Further examples include the locating of a turning sander adjacent to the turning lathes, and the positioning of scroll or jig sanders near the scroll saws and routers. A further point of interest is involved in the locating of two triple-drum sanders in tandem, or with the second machine at right angles to the first, to enable the tail-man of the first unit to feed the second machine and to permit sufficient savings to warrant the replacement of such machines at the conclusion of the normal depreciation period. Such an arrangement also offers interesting possibilities in the event of a complete collapse of one of the two machines through mechanical failure, etc.

Evaluation of the savings and potential product improvement of resulting from such relocation of equipment becomes of increased interest when it is realized that the further this practice is pursued, the more clear it becomes that the operations remaining for the conventional cabinet room or sanding room to perform are simply polishing operations. In that sense, it is significant to study further the effect of such intermediate and final sanding of wood surfaces which can truly be considered in line with the title of this paper.

Conclusion

The trends we note from the above discussion are evident, while the extent to which they will be pursued and practiced rests with the future. As so very many know only too well, the woodworking industry is a good example of a business in which it is more necessary today than ever before to plow a reasonable percentage of profits back into the business to increase productivity, as well as quality, of product. Because of recognition of these factors by so many individuals in the woodworking trade in recent years, the writer feels the trend will continue along these distinct lines: (1) towards more intimate interest in the finishing and operations, (2) towards the use of finer grit sizes of coated product materials, and (3) towards more intimate interest in the finshing of the different types of woods incorporated into any one piece of furniture, to the end that the final finishes of the various parts thereof will become more uniform.

TECHNICAL SESSION VII

Wednesday, March 24, 1948, 10:30 A. M.

General Subject: Dielectric Heating

Chairman: James F. Hamilton, Technical Service Director, Perkins Glue Company, Lansdale, Pennsylvania *(Northeast Regional Board Member, FPRS)*

Recorder: Roy M. Carter, Utilization Technologist, Northeastern Forest Experiment Station, Philadelphia, Pennsylvania *(Northeast Regional Board Member elect, FPRS)*

FOREST PRODUCTS RESEARCH SOCIETY

Principles of Dielectric Heating

Robert M. Baker

Advisory Engineer, Industrial Electronics Division, Westinghouse Electric Corporation, Baltimore, Maryland

Dielectric heating is a new tool supplied to and accepted by the industrial engineer in recent years. Unfortunately, its application requires a certain amount of new knowledge and new concepts on the part of the user. This is especially true during the setting up and preliminary operating stages, because after it is in operation it can be made so nearly automatic that even an unskilled operator may use it. This article attempts to give a clear, simple story of radio frequency generators and the dielectric heating process, with the hope that this will make the users' problems easier and clarify some of the misunderstandings which have existed.

Radio-frequency power is not something mysterious. It is describable in terms of volts, amperes, and power factor just like the familiar 60-cycle power taken from the supply lines. The power output from a radio-frequency generator is always less than the power taken from the 60-cycle line, so it is not a means of getting something for nothing. On the other hand, it is characterized by concentration of the heat just where it is needed and by elimination of the long heating time often necessary to allow heat to soak in from the outside.

Radio-frequency equipments are relatively expensive and their overall efficiency, from 60-cycle power input to power in the work, is in the order of fifty percent. They are generally justified by increased production, simplification of process, or improved product quality. The essence of dielectric heating is speed, and an application can be justified only by making an economic analysis and comparing the cost with alternate methods of heating.

Introduction

SO MANY articles have been written on the subject of dielectric heating that one might question the justification of another. The author hopes, however, to find justification by presenting in a simple brief manner the story of radio-frequency generators and their application to production problems in the woodworking industry. It is not the purpose to describe applications or processes in detail, but rather to point out the principles involved.

Definition of Dielectric Heating

Dielectric heating, as the name implies, is the process of generating heat in dielectric materials, i.e., materials which are inherently poor conductors of electricity, by placing them in a strong alternating electric field. It is generally accomplished by placing the material between a pair of metal plates, called electrodes, and applying to these plates a radio-frequency voltage of several thousand volts. The heating effect is different for different materials and is a function of the applied frequency and voltage.

Generators for Dielectric Heating

The frequencies most commonly used for dielectric heating range from two megacycles (2 MC) to forty megacycles (40 MC) per second, depending on the job to be done. Power at these frequencies is generated by vacuum tube oscillators, commonly referred to as radio frequency or R. F. Generators. Although certain propaganda has, in recent years, tended to envelop all things electronic in a kind of romantic mystery, there is actually nothing mysterious about an R. F. Generator. It is simply a frequency converter which draws 60-cycle power from the power line and delivers R. F. Power to its output terminals and to the load. The output power is measured in volts, amperes, and power factor just like the familiar 60-cycle power taken from the supply lines; the only real difference is one of frequency. Because standard low frequency volt-meters and ammeters will not function properly at radio frequencies, it has been necessary to develop special radio-frequency volt-meters and ammeters. A good practical R. F. Watt Meter has not yet been developed and it is, therefore, customary to measure R. F. Power output in terms of heating effect observed or by some other indirect method.

The principal components of an R. F. Generator are:

1. The plate transformer, which steps up the 60-cycle line voltage to a high value.
2. The rectifier tubes, which convert the alternating current to direct current.

3. The oscillator tubes, which act as high-speed switches to break up the direct current into pulses of the desired radio frequency.
4. The tank circuit, which, being a resonant circuit, is excited by the pulses so as to build up a high circulating current in this circuit and a high R. F. voltage across it.
5. The load coupling and load matching network, which is adjusted to obtain proper flow of power from the tank circuit to the load circuit.

The dielectric heating load may be connected directly to the terminals of the R. F. Generator, or it may be located some distance away and be connected to the generator by a suitable shielded transmission line.

Two typical Westinghouse R. F. Generators are shown in Figures 1 and 2. The first is a 10 KW, 5 MC generator used with semi-automatic press in the edge gluing of boards to form large panels. The second shows a 100 KW, 13.6 MC generator used for such applications as curing and drying sponge rubber products or bonding thick laminates such as plywood or micarta.

Shielding of Dielectric Heating Equipments

The R. F. generators used for dielectric heating are similar in many respects to radio transmitters. These generators and their associated circuits will, therefore, if not properly shielded, radiate energy into space and cause interference to radio reception and other radio services. Shielding is accomplished by surrounding the load electrodes and all associated circuits with a metal housing, consisting usually of thin aluminum or copper sheet well bonded at the joints. The manufacturer supplying the R. F. generator will either supply the necessary shielding or will provide the necessary information to the user. The generator itself, housed in a metal cabinet, usually will not radiate sufficiently to cause trouble.

Fig. 1.--A 10 KW, 5 MC., R. F. Generator used to edge glue large panels.

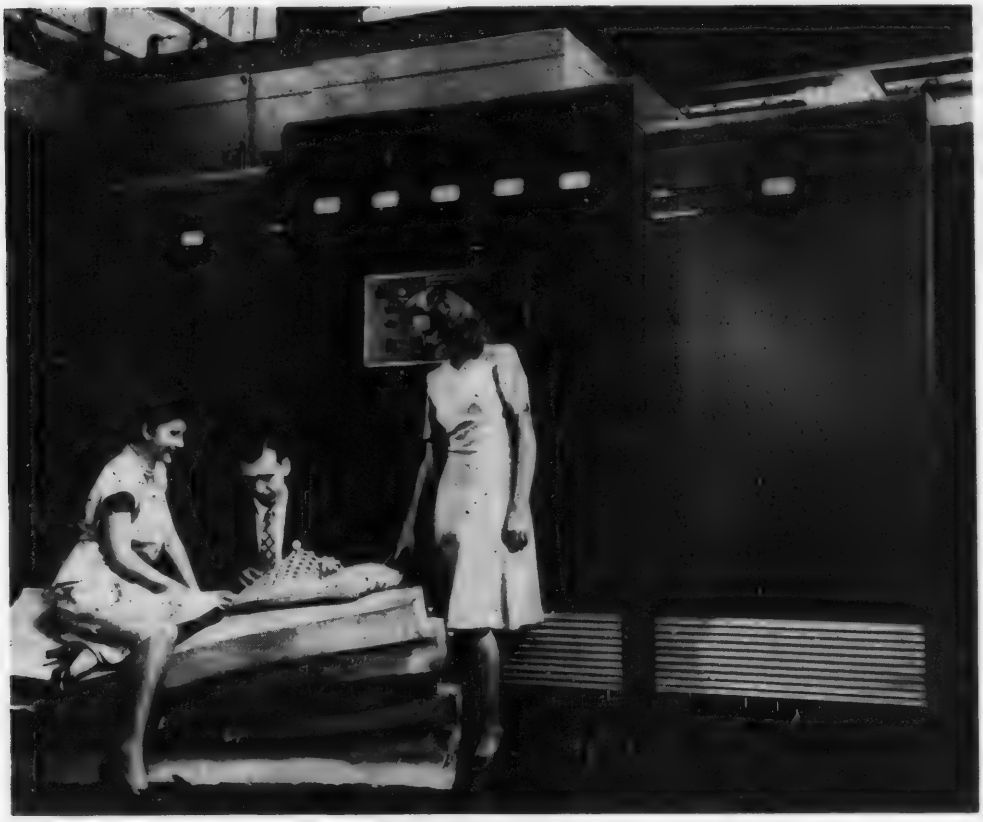


Fig. 2.—A 100 KW, 13.6 MC R. F. Generator used to process sponge rubber or bond thick plywood boards.

A Typical Dielectric Heating Load

In order to discuss the dielectric heating process in a little more detail, the problem of gluing two flat pieces of wood together to form a single piece of double thickness will be considered. Glue is spread on the contacting surfaces and the pieces are placed under pressure between the two electrodes A and B shown in Figure 3. R. F. voltage of several thousand volts applied across the electrodes produces a strong alternating electric field in the wood. This field, acting on unbalanced electric charges, actually shakes the molecules of the wood and a kind of internal friction causes heat to be generated. Since the field is essentially uniform throughout the wood, it will be uniformly heated in a matter of seconds or minutes to the setting temperature of the glue. The size of generator required is proportional to the weight of wood and temperature rise and is inversely proportional to time of heating. Thus, in bonding large thick sections of plywood, it will usually be desirable to use a heating time of 20 minutes or more to limit the size and cost of the R. F. generator, although small pieces can be bonded economically in a matter of seconds.

The load of Figure 3 is electrically nothing more than a capacitor consisting of two metal plates separated by the wood which acts as the dielectric or insulation. When R. F. voltage is applied to the plates, R. F. current flows in the circuit. The total current (1_o) is made up of two components as shown in Figure 4. One is the small current (1_r) which is in phase with the applied voltage, and which actually represents the power input to the load; the other is the current (1_c) which is the charg-

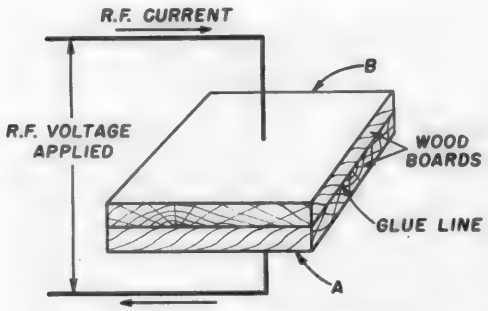


Fig. 3.—A typical dielectric heating load.

ing current for the capacitor and which contributes nothing to heating. If dry wood completely fills the space between the plates, it will be found that the power factor at the load terminals is approximately 0.04 over a wide range of frequencies in the megacycle range. It is said, therefore, that dry wood has a power factor of 4.0 percent. Various dielectric materials have different power factors and different dielectric constants. The product of dielectric constant and power factor is called the "loss factor" of a material, and is a measure of the ability of the material to heat in an R. F. field. For instance, wood has a loss factor of about 0.25 and is easy to heat. Polystyrene has a loss factor of about 0.0005 and is so difficult to heat that it makes good radio-frequency insulation.

Dielectric Heating is Through Heating

The obvious advantage of dielectric heating is its ability to generate heat inside the article being heated. Thus, when used to set glue in a thick stack of plywood, the center heats just as soon and just as rapidly as the outer surface. It is not necessary to wait long periods for the heat to soak in from the outside, as is the case when heating is obtained from heated platens in contact with the surfaces of the stack. It follows that dielectric heating is most economically applied where thick sections, difficult to heat by other methods, are involved. One outstanding exception to this rule is in the bonding of thin curved plywood sections for making radio cabinets, furniture, etc. In this case, dielectric heating is more than competitive economically, because it permits making cheap molds sawed simply from a piece of good dry wood and lined with thin sheet copper to form electrodes.

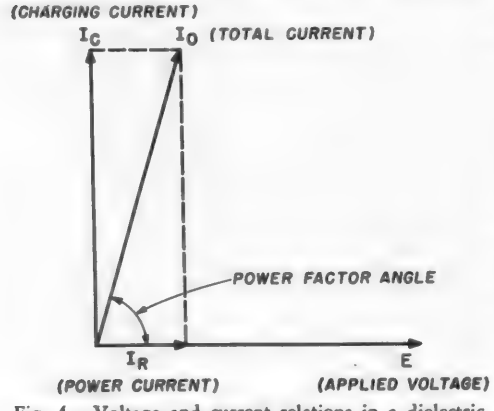


Fig. 4.—Voltage and current relations in a dielectric heating load.

Air Gaps in Dielectric Heating

In Figure 3, a typical dielectric-heating load was illustrated with both electrodes in contact with the material to be heated. Heating can also be accomplished when one or both electrodes are separated from the material by an air-gap. This fact is often useful in continuous heating or drying operations, where articles are carried on an endless belt between a pair of electrodes. In such an arrangement, a metal mesh belt is often used and made to serve as the lower electrode.

The penalty one pays for the convenience of an air-gap is two-fold. First, it reduces the power factor at the load terminals which makes the load a more difficult one for the R. F. generator. Secondly, it increases the voltage which must be applied to the electrodes and thus increases the danger of flashover.

Choice of Frequency

As mentioned earlier, the conventional frequencies for dielectric heating range from 2 to 40 megacycles per second. As the frequency is increased, the voltage required to do a given job of heating decreases. It is good practice to use as low a frequency as possible, consistent with freedom from flashover or voltage breakdown troubles. For such a job as illustrated in Figure 3, one could use the standard frequency of 13.6 MC., although for a very large load, a lower frequency might be indicated. For some

special small jobs, a frequency of 100 MC or higher is sometimes used.

Radio-Frequency Edge Gluing

Figure 5 shows schematically an edge-gluing press used in making large panels from a number of narrow boards. The edges of the boards are spread with glue and the boards are laid side by side between two metal plates which form electrodes. Side and top pressures hold the boards securely together and R. F. power applied to the electrodes heats the glue and causes it to set in a time of 20 or 30 seconds. The finished board is ready for planing and further processing.

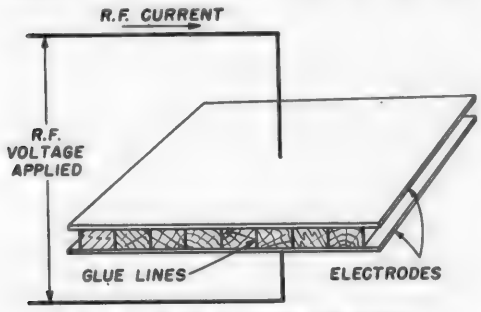


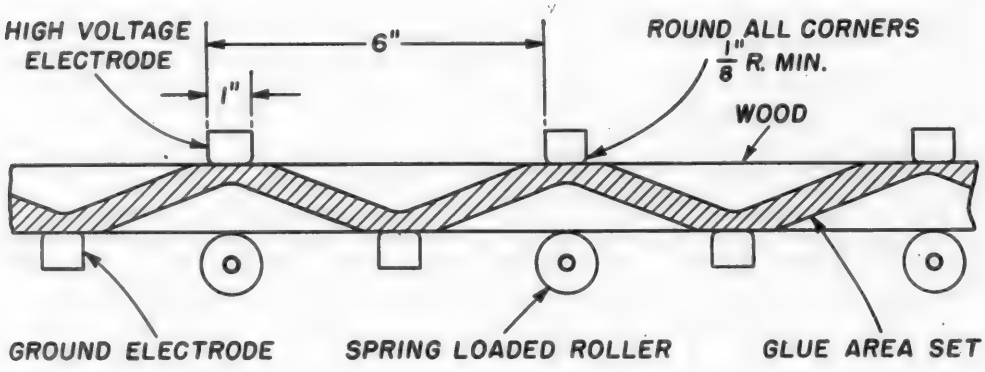
Fig. 5.—Radio frequency edge gluing.

This method of using radio-frequency power for heating is different in several respects from the more conventional method illustrated in Figure 3 and, for the particular job which it does, has several distinct advantages. It will be noted, first of all, that the field is applied parallel to the glue lines. In fact, if excess glue squeezes out of the joints and contacts the electrodes, it is obvious that the voltage is applied directly across the glue line. The glue, being wet, is a fairly good electrical conductor and the voltage applied to the electrodes causes a current to flow through and heat the glue. Because most of the heat is generated in the glue line, the glue is set without appreciable power being wasted in heating the wood. But why, one might ask, does one not simply apply a low frequency or D–C voltage across the electrodes? There are at least three reasons why this is not practical.

First, the picture above was idealized by assuming that the wet glue squeezes out and contacts the electrodes at every joint. Actually, due to different board thicknesses and other irregularities, there will always be some glue lines not contacting the electrodes. Radio frequencies overcome this difficulty by allowing current to flow as capacity current across any gaps which exist and then concentrate in and flow by conduction through the wet glue line toward the opposite electrode. *Secondly,* if low frequency voltage was applied to the electrodes, the glue would tend to dry or set first at points of high current concentration and this would break the current path and preclude the possibility of further heating to completely set the glue line. Radio frequencies overcome this difficulty by the same process of allowing capacity currents to flow around any point in the conducting path which acquires a high resistance. *Thirdly,* there is, with radio frequencies, always some true dielectric heating in the glue line, especially as the glue begins to set. That is, as the heating from actual current conduction (ionic conduction) through the wet glue drops off, the molecule shaking effect of the electric field takes over and supplies the heat to complete the cure.

It is clear from the discussion above that the edge-gluing process could be carried out with an air-gap between the top of the boards and the upper electrode. Advantage is taken of this fact in some continuous automatic presses. Whereas a batch type press, operating with both electrodes pressed against the wood, employs a frequency of from two to five megacycles per second, a continuous automatic type press, operating with a small air-gap between the upper electrode and the wood, may operate with a frequency as high as 13.6 megacycles per second.

In Figure 5 and in the discussion of the principles of edge gluing given above, it was indicated that both electrodes consisted of solid metal plates. It has actually been found by experience that a grid type electrode, such as that illustrated in Figure 6, has certain distinct advantages. This electrode structure consists of a set of one-inch wide bars spaced from four to six inches on centers above the boards and all connected to one terminal of the generator; and a second similar set of bars located under the boards, displaced as shown, and connected to the other terminal of the generator. To sim-



ELECTRODES FOR PARTIAL GLUE LINE SETTING
(SECTION THROUGH GLUE LINE)

Fig. 6.—Grid type electrodes for edge gluing.

plify the insulation problem, it is common practice to ground the lower set of bars to the frame of the machine and operate the generator circuit with one side grounded. With this arrangement, the currents flow from upper to lower electrodes and vice versa to heat and set the glue in a zig-zag path as indicated. With about one-third the total area of glue line set in this manner, the panel is sufficiently strong for planing and subsequent processing. Residual heat in the region of the glue line causes the remaining two-thirds of the glue-line area to set in about one hour.

The advantages of the grid type electrode structure are two-fold. First, it permits the gluing of larger panels in a given time with a fixed generator output and, second, for a given size of panel, it presents a higher electrical impedance and is therefore easier to match properly to the generator.

Stray-Field Heating

It is not always necessary to have electrodes on both sides of the piece being heated. Consider the arrangement illustrated in Figure 7. It is desired to spot set the glue between a thin veneer and a heavy wood section, in order only to hold the veneer in place until the final complete setting of glue is accomplished in a press or by some other method. R. F. voltage is applied between the two small electrodes and a fringing field, indicated by the arrows, dielectrically heats the wood and a limited area of the glue line. This is called stray-field heating because the piece being heated is not in a main field between two electrodes but is being heated simply by the stray or fringing field of these electrodes. Small hand-operated guns made with special small electrodes, and with a trigger to turn power on and off, are used for many jobs similar to the one indicated.

Thermal Requirements in Dielectric Heating

It is necessary only to remember that it requires just as many Btu. of radio-frequency energy to raise so many pounds of material so many degrees in temperature or to evaporate so many pounds of water, as it does when using steam or any other method of heating. It should also be remembered, however, that with R. F. heating, the heat can be generated just where it is needed and losses from the system are minimized. After determining the number of actual Btu. per hour required to do a job, one can divide this number by 3413 to obtain the K.W. or R.F. power required from the generator.

As a few simple rules of thumb one should remember:

1. One K.W. will raise the temperature of one pound of wood approximately 140° F. per minute.

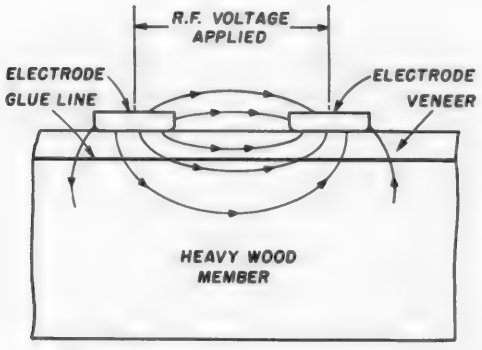


Fig. 7.—Stray-field dielectric heating.

2. One K.W. will, when used for edge gluing, set about 250 square inches of glue line per minute, in soft woods, and somewhat less than this in hard woods, depending on the type.

3. One K.W. will evaporate approximately three pounds of water per hour.

Economics

Radio-frequency equipment is not cheap, but in many applications it is justified on the basis of high production obtained and on its ability to put the heat where it is needed. As a very rough estimate, one can assume that an R. F. generator will cost about $500 per K.W. of output, at ratings of 10 KW and above. The efficiency is conservatively estimated as 50 percent from the 60-cycle input to power in the load. The first major step in any application which appears technically feasible is an economic analysis, to determine the cost per pound or the cost per piece for doing a given job. If this appears favorable in comparison to alternate methods for doing the same job, it is almost certain that one can work out the technical details of the application.

Discussion

Mr. M. E. Dunlap (U. S. Forest Products Laboratory): Mr. Baker has presented a very useful paper, describing in a very simple and understandable way the operation of high-frequency dielectric heating equipment and methods. It is a very excellent introduction to the papers that follow. He has not only stated the principles involved in the use of high-frequency electrical energy but has pointed out the limitations, particularly as to economics, giving simple rules that would enable a prospective user to make an estimate of the probable costs and to determine whether an economical operation is a possibility. A person considering the purchase and installation of high-frequency dielectric heating equipment will find it a valuable guide.

Mr. Arthur L. Mottet (Long–Bell Lumber Company): I should like to hear some comments as to the relative advantages and disadvantages of "double-ender" and "single-ender" radio-frequency generators in various woodworking applications.

Mr. Baker: Double-end or single-end describes the type of circuit used in an R-F generator. Mr. Mottet undoubtedly refers to whether the leads coming out of the generator are both hot, or if one is at ground potential and one is above ground potential (single-ended). In a few applications, it is advantageous to have two hot leads brought out to feed a balanced load. More often, as for instance when a conveyor or press forms one of the electrodes, it is preferable to have one of the electrodes at ground potential. Therefore, in designing a line of standard generators for industrial application, it is preferable to design the generators for single-end operation. Such a generator can be used to feed a balanced load (both electrodes hot) by the addition of a relatively simple external network.

FOREST PRODUCTS RESEARCH SOCIETY

Glues For Use With High-Frequency Heating

Lloyd E. Dimond

Chemical Engineer, Thermex Division, The Girdler Corporation, Louisville, Kentucky

Three principal methods are employed in curing glue lines with heat created by high-frequency energy, a technique that is rapidly becoming of major importance in the woodworking industry. They are (1) perpendicular heating, (2) parallel heating, and (3) stray-field heating. This paper deals with the selection of glues most suitable for these three widely used high-frequency applications, the advantages and limitations of the new technique, and the need for additional research to find more satisfactory glues for parallel heating.

IN RECENT years, many new and remarkably improved gluing techniques and glues have become available to the woodworking industry.

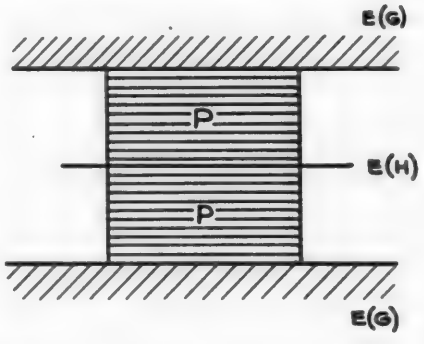
Of the new techniques, probably the employment of high-frequency energy in curing heat-sensitive glues has proved the most impressively successful. It is being used both to enhance the quality of wood products and to bring about substantial operating economies.

The three principal ways of applying high-frequency energy are generally known as (1) perpendicular heating, (2) parallel heating, and (3) stray-field heating. It is of the utmost importance that proper glues be used if satisfactory results are to be obtained. This paper will briefly discuss these three applications and cover in considerable detail what extensive laboratory and field work has indicated are the most desirable types of glues under varying circumstances.

Perpendicular Heating

The term perpendicular heating is used where the high-frequency field is perpendicular to the glue lines, or the electrodes are parallel to the glue lines. The wood and glue are heated simultaneously at substantially the same rate. This type of heating is employed in making both flat and curved plywood, laminated wood, furniture panels, and the like. One simplified set-up, with a center electrode, is shown in Figure 1. Another simplified set-up for curved work is shown in Figure 2. A primary requirement is that the glue be heat-sensitive, i.e., its setting reaction must be substantially accelerated as its temperature is raised. Examples are urea resins, both hot and cold setting; phenolic resins; resorcinol resins; soybean glue; and blood glue. While all of these glues can be made to serve, some of them are much more desirable than others. Glues such as high-temperature phenolics, that normally require relatively high temperatures to set in a short time, are not as efficient as cold-setting urea resins, resorcinols, and other glues that set in a few hours at room temperature.

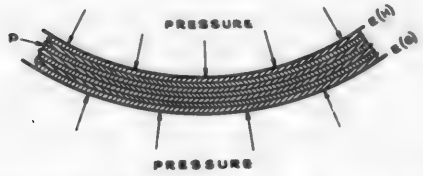
There is still another consideration. Plywood panels fabricated with a high temperature adhesive should have a moisture content of preferably less than five percent. Otherwise an excessive amount of heat will be dissipated in boiling away water. In addition, the moisture will often collect in various places and cause hot spots, blow-ups, and similar irregularities.



PERPENDICULAR HEATING SET-UP

E(H) - HIGH-VOLTAGE ELECTRODE
E(G) - GROUND ELECTRODES
P - PLYWOOD BUNDLES

Fig. 1.



PERPENDICULAR HEATING SET-UP FOR CURVED WORK

E(H) - HIGH-VOLTAGE ELECTRODE
E(G) - GROUND ELECTRODE
P - CURVED PLYWOOD

Fig. 2.

Cold-setting glues, on the other hand, may be employed efficiently where the moisture content of the wood is as high as ten percent. This is due, of course, to the fact that such glues are more sensitive to heat. They cure faster, and lower temperatures or shorter time cycles are used.

High-frequency energy gradually raises the temperature of the load as long as the power remains on. Therefore, before production is started, it is necessary to know the setting characteristics of various types of glues and the final temperature that each should reach at the end of the heating cycle. In a six-minute heating cycle, for instance, a cold-setting urea resin will require a final temperature of only about 185° F., compared with the final temperature of about 300° F. required for a high-temperature phenolic. So it is easy to see that a cold-setting urea resin makes it possible to produce considerably more glued-up material in the course of a day with a high-frequency generator of a given size than could be produced by using a high-temperature phenolic glue. Figure 3 shows some curves that can be used

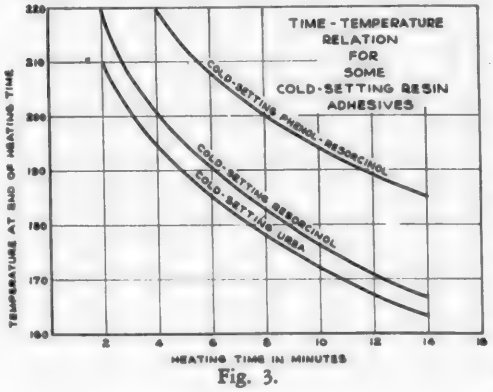


Fig. 3.

as a guide for determining the final temperature required for high-frequency gluing, when cold-setting urea resins, cold-setting resorcinol resins, or some cold-setting phenol resorcinol blends are employed. These curves are helpful for general reference purposes. But it should be borne in mind that there are some variables in the setting speed of different glues of the same calssification. Figure 4 shows more time-temperature relationships for some average warm-setting and high-temperature phenolics. In establishing the heating time cycle for a given production objective, the amount of material it is desired to produce must be determined. Then an adhesive that will efficiently produce the desired qualities in the glued-up article should be selected. With this information, the

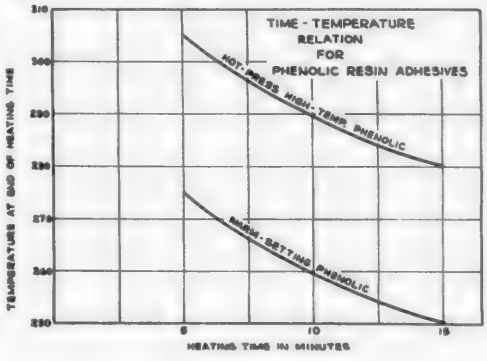


Fig. 4.

right size of high-frequency generator can be purchased. When the generator is installed in the plant the final temperature is usually checked with thermocouples at the end of the pre-established heating time. Then small adjustments are made in the heating cycle, in order to correlate it with the time needed for spreading and laying up, loading and unloading the press, etc. Generally, the practice is to make the heating time somewhat less than the calculated figure and obtain a partial cure that is sufficient to allow the load to be removed from the press. The loads are warm stacked for an hour or so, thus taking advantage of their heat to obtain a complete cure. After a few days' experience, the operator becomes familiar with the equipment and the heating times for each of the layups being produced. Thereafter, the final temperature no

longer has to be checked with the thermocouples. The operator finds that the instruments supplied with the high-frequency generator enable him to repeat his results with sufficient accuracy for practical purposes.

Since a longer heating cycle calls for a lower final temperature, it is often expedient to arrange the layups in such a manner that a fairly large amount of material is heated at one time. Extending the heating period with a given high frequency generator obtains still more efficient operation. For example, using cold-setting urea resin and a heating time of two minutes, about 72 Btu's per pound of wood must be supplied before the material can be removed from the press. This compares with about 46 Btu's per pound of wood required to obtain the same cure if a 12-minute heating time were employed. Figure 5 shows a curve that further

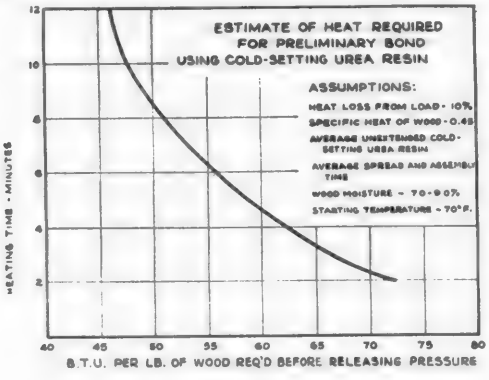


Fig. 5.

illustrates this point. Obviously, if 20 units are glued in 12 minutes, the production rate is faster than if two units are glued in two minutes. This is a factor often overlooked by some when they are considering high-frequency gluing for a specific operation.

Parallel Heating

The term parallel heating is applied where the high-frequency field is parallel to the glue line (the electrodes being perpendicular to the glue line). A simplified set-up for parallel heating is shown in Figure 6. In this case the glue is virtually the only part of the load heated. While the wood and glue compete for the high-frequency energy, the wet glue is much more conductive and therefore absorbs the

END VIEW OF PARALLEL BONDING SET-UP

E(H) - HIGH VOLTAGE ELECTRODE
E(G) - GROUND ELECTRODE
A - DISTANCE BETWEEN ELECTRODES
B - WIDTH OF WOOD PIECES
W - VARIOUS WOOD PIECES BEING GLUED
G - GLUE LINES

Fig. 6.

greater portion of the energy available. This results in a very efficient bonding operation, because the weight of the glue being heated is normally very little compared with the weight of wood being bonded. The glue requirements for parallel heating are much more exacting than those for perpendicular heating. First, the glue must be of a heat-sensitive, cold-setting type. The reason is evident when we examine the theory of parallel heating. Here the wet, highly conductive glue takes up almost instantaneously large amounts of high-frequency energy. This energy brings the glue to its boiling point (230 to 240° F.) very quickly, usually in one to three seconds. As long as the glue is still moist, it continues to draw high-frequency energy and stays at its boiling temperature until it cures and the glue line dries out. The glue line then is less conductive and its ability to draw high-frequency energy is not much more than the wood's. The temperature of the wood in the meantime has been raised very little. However, if the power is not shut off at this stage, the wood will gradually heat up. A production cycle in parallel heating is ordinarily ended when the glue cures and dries out. The widest use for parallel heating is in the edge bonding of panels for furniture and other similar purposes. Practical time cycles for edge bonding usually are in the range of 10 to 60 seconds. The lumber is held in place in a conventional edge-bonding press, which provides a top retaining pressure of from one to five pounds per square inch and a side pressure of from 150 to 400 pounds per square inch. High-temperature glues do not work at all with parallel heating. Even if they are used wet, so that they will draw high-frequency energy,

they ususally dry up and quit drawing this energy before they have cured. Some cold-setting resorcinol resins are relatively non-conductive. They do not draw high-frequency energy at a very rapid rate, and therefore slow down production when used for edge bonding, especially when the amount of power available is not unlimited. Other cold-setting resorcinol resins, and certain blends of resorcinol resins with small quantities of alkaline phenolic resins, possess the ability to draw high-frequency power well when used in parallel heating and they work quite satisfactorily for edge bonding. We have then a second condition that glues must meet to be useful for parallel heating, namely, that they must be sufficiently conductive to draw high-frequency power at a much faster rate than the wood being glued. There are great differences in the conductivity of glues considered for parallel heating. Some are too conductive and no matter how carefully the high-frequency power is applied they usually arc through the glue line if sufficient power is used to obtain a practical time cycle. Highly alkaline glues, such as casein and soybean glues, arc very badly when used in parallel heating and for this reason are not employed in this type of operation. We have then a third condition that a glue intended for parallel heating must satisfactorily meet, namely, that it cannot be too conductive. In most cases, cold-setting urea resins appear to best meet the requirements in parallel heating and are used almost exclusively. If a boil-proof bond is needed, cold-setting resorcinols with the proper conductivity are normally specified.

The extremely short curing times in parallel heating have brought up the question of the quality of glue joint obtained. It has been asked if a cold-setting urea resin penetrates the wood pores sufficiently to obtain a good bond, when cured by high-frequency energy in a matter of seconds. In order to investigate this point, a series of tests were made using curing cycles ranging from 6 to 180 seconds. A cold press control was employed. The tests show no significant differences in bonds obtained by the shortest cycle or the longest cycle, or by parallel heating or cold clamping. Apparently, in a very short cycle, the glue's viscosity drops quickly (in a mater of a second or so) and remains at this low viscosity long enough so that the applied pressure permits it to penetrate the wood pores to about the same distance it would if room temperature clamping were employed.

Every process seems to be accompanied by problems, some of which cannot be foreseen at the outset. Edge bonding with parallel heating is no exception. However, in general, it has been a most successful tool for the woodworking industry. Thus far, few difficulties have been experienced in the edge bonding of low-density woods, such as poplar, basswood, ponderosa pine, etc. The edge bonding of high-density woods requires the most adjustments in procedures. The high-density woods must be more carefully jointed and, in general, a better all-around gluing technique must be used. Apparently this is because the glue must be more completely cured and the bond much stronger before the load is removed from the press. In edge bonding woods that are relatively good conductors (such as ash and swamp gum), it is often necessary to adjust the conductivity of the glue line in relation to the wood, usually in the direction of making it more conductive. There are two ways to increase the power absorbed by the glue. One of these is the adjustment of frequency. Lower frequencies tend to heat the glue line more than higher frequencies when the same amount of power goes into the load. If needed, the frequency is adjusted to take advantage of this fact. This is shown clearly in the example in Figure 7. It should be noted that to cure the glue line in this particular case, 8.8 megacycles required about three times as much power as 1.7 megacycles. However, lower frequencies are accompanied by higher voltages for the same power input. Higher voltages tend to flash over between

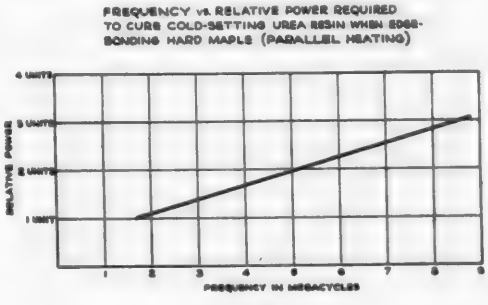

FREQUENCY vs RELATIVE POWER REQUIRED
TO CURE COLD-SETTING UREA RESIN WHEN EDGE-
BONDING HARD MAPLE (PARALLEL HEATING)
RELATIVE POWER
FREQUENCY IN MEGACYCLES

Fig. 7.

electrodes or cause arcing through the glue line. Frequencies used commercially are usually a compromise to produce the best practical results. The conductivity of the glue line can be increased by the introduction of small amounts of an electrolyte, such as common table salt. There have been a few cases in the field where the curing time was particularly long because the wood absorbed excessive high-frequency power. In some of these instances, the addition of 1½ percent table salt (based on the dry weight of the cold-setting urea resin) reduced the time cycles to less than one-half their former length. Figure 8 shows some compara-

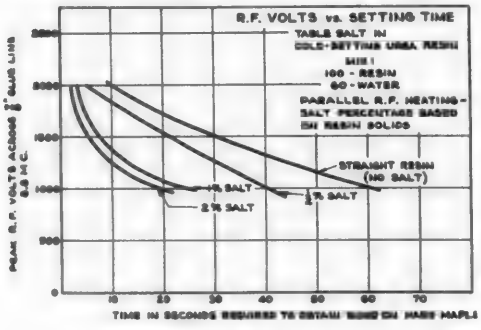


Fig. 8.

tive results obtained in the laboratory when various percentages of table salt were added to urea resin. The addition of table salt to cold-setting urea resins, for edge bonding with high-frequency parallel heating, is no cureall, however, and often it has been found to do more harm than good. The principal limitation to the use of table salt in cold-setting urea resins for edge bonding is that it sometimes causes too much power concentration in the glue line, resulting in occasional arcs and burning at the glue line. It should be used only where the wood is too conductive or where a relatively small high-frequency generator is connected with a relatively large edge-bonding press.

Another interesting difficulty encountered in edge bonding was the burning of glue joints when attempting to glue white oak. This burning was not what is ordinarily termed arcing. It appeared to be the over-heating of the glue joints, producing charred streaks within the joint and parallel to the electrodes. Laboratory and field experiments indicated that the filler in the cold-setting urea resin used (in this instance, walnut shell flour) was somehow causing this runaway heating condition. Also, it was found that any other filler, for example wheat flour, would cause the same effect. Apparently the pore structure of white oak is such that the filler prevented the moisture from leaving the glue-line area rapidly enough, thus causing the glue-line heating to go on unabated. When a cold-setting urea resin without any filler was employed, the white oak was edge bonded in a very short cycle without any further burning difficulties. Other experiments have indicated that it is quite necessary for the glue moisture to leave the glue-line area quickly in order to prevent burning of the glue joint. Dull jointer knives that tend to polish off the surfaces to be glued will increase the burning tendency.

Glues that are to be used for parallel heating call for additional research. Some of the factors that should be investigated more thoroughly for their effect on burning tendency are speed of set in a high-frequency field, and various types, amounts, and sizes of the particles of fillers employed.

Perhaps a word should be said about some limitations of parallel heating when using the more common type high-frequency generator with a high voltage lead and ground lead. Where the time element is to be approximately 60 seconds or less, the distance between the electrodes, or the length of travel of high-frequency power through the glue line, should be about three inches or less. This is the dimension "A" shown in Figure 6. Greater dimensions than this can be handled, possibly up to five inches or so, but the efficiency of the process starts decreasing because the entire wood mass tends to heat up more, thus setting less glue with a given amount of heat and usually extending the heating cycle from seconds into minutes. Also, if each of the boards being edge bonded is much less than ½ inch (dimension "B" shown in Figure 6), the advantages of parallel heating start diminishing, even though the distance between the electrodes, or the thickness of the panel, is less than three inches.

Stray-Field Heating

Stray-field heating is quite similar to parallel heating, particularly in the types of glues used,

the time element involved, and in the general theory. It differs principally in the electrode arrangement and in the type job performed. Ordinarily, a stray-field electrode (for example the type used to bond a plywood panel to a framework core) consists of a series of parallel metal bars so spaced and arranged as to cause the field to pass through the desired glue line and set it up. These bars are generally imbedded flush in a wood pressure surface and so connected that they are at alternate high and ground potentials. One such electrode arrangement for stray-field heating is shown in Figure 9. The biggest use for stray-field heating have been in gluing panels or veneers to a framework core, and in the assembly gluing

END VIEW OF STRAY FIELD SET-UP

E(H) - HIGH-VOLTAGE ELECTRODES
E(G) - GROUND ELECTRODES
P - PLYWOOD PANEL
W - WOOD MEMBERS
G - GLUE LINES

Fig. 9.

of furniture parts. The general theory is that the high-frequency energy follows the path of least electrical resistance, in this instance the wet glue line in the proximity of the electrodes. The efficiency of stray-field heating is higher than perpendicular heating, but less than parallel heating. In stray-field heating a small amount of wood is usually heated along with the glue line. It has been found, however, that efficiency can often be increased somewhat if the glue is made more conductive by the addition of small quantities of table salt. The salt is added in the manner explained in the discussion on parallel heating. The glues used for stray-field heating are, in general, the same type as are used in parallel heating. Since arcing and burning difficulties are not so pronounced, higher voltages can be applied. Often glues that set at a somewhat higher temperature than the cold-setting types can be used; melamine fortified hot-press urea resins, for example. However, these glues will give less efficient results than the cold-setting resins because more power is required to obtain the same time cycle, or a longer time is required when the same amount of power is employed. Also, all glues used in stray-field heating must have the ability to pull the high-frequency power. A strictly non-conductive glue will not work very well in stray-field heating, regardless of its other fast setting characteristics.

Conclusions

In judging the suitability of a woodworking glue for use with high-frequency heating, it first must be determined whether the glue is to be employed in perpendicular, parallel or stray-field heating.

Perpendicular heating is used for making both flat and curved plywood, laminated wood, and furniture panels. Almost any heat-sensitive glue can be applied in perpendicular heating. But glues of the cold-setting type are more efficient from the production standpoint.

Parallel heating is the most efficient means of gluing with high-frequency heat. It is used to the greatest extent in edge bonding furniture panels. Glue requirements for parallel heating are much more exacting than for perpendicular heating. The glue must be of a cold-setting type and conductive enough to draw high-frequency energy well, but not conductive enough to cause arcing.

Stray-field heating is similar to parallel heating and is used for furniture assembly and gluing plywood panels to framework cores. Cold-setting type glues, similar to those used in parallel heating, work best in stray-field heating. The efficiency of stray-field heating, while quite high compared to perpendicular heating, is somewhat less than parallel heating.

The need for additional research is greatest on glues that are to be used for parallel heating. This research should include an investigation of the effects of various glue components on the burning tendency.

Discussion

Prof. A. H. Bishop (New York State College of Forestry): Mr. Dimond has mentioned the large variation in the conductivity of synthetic resin adhesives; also that they should be good conductors but still resist arcing. We have measured the R/F conductivity of the wet mix of quite a few urea formaldehydes. Their R/F conductivity at 1-15 megacycles varies from 100

to 4200 micro mhos per centimeter. Most of them show an increase in conductivity as the frequency is increased, although several are not affected by increasing the frequency up to 15 mc. In no case would the magnitude of increment exceed 800 micro mhos per centimeter.

Mr. S. F. Stevens (Roddis Lumber & Veneer Co.): Mr. Dimond is familiar with our set-up, where a 16kg unit furnishes stray-field heating to bond a 3-ply panel to a framework (honeycomb) core with urea resin-glue. Panels made in the plant generally have a moisture content between 5 and 7 percent. The source of some of our troubles in gluing was traced to "wet" panels, and a continuous check on the moisture content of the panels with both types of moisture meters (needle and contact) showed the following:

(1) Moisture content of the panels in the range of 6 to 9 percent was best for gluing.
(2) Ten percent was on the border line, although a longer heating cycle would compensate somewhat for the wetter wood.
(3) At over 10 percent, poor bonds resulted because the heat was used to "dry" the wood rather than to cure the glue. In fact, wet panels, after a heating cycle, could be stripped from the core without any difficulty and the glue line looked thin and starved.
(4) Wet panels can be readily discovered by the steam generated from the wood; by the action of the amperage indicator; and the wood feels damp to the touch.

In addition, I would like to add that controlling the viscosity of the urea resin mix will help in shortening high-frequency heating cycles and give better bonds. Use a "thicker" mix than one used for cold or hot pressing, even though it adds to the glue-line cost. It will also decrease the amount of arcing due to ooze out on the edges.

Mr. Martin Hawrylow (Pluswood Inc.): We talk about selecting the right glue for high-frequency bonding operations, yet how much do we know about the conditions we are trying to bridge by selecting the so called "correct adhesive".

We normally think of dielectric heating in terms of "uniform" temperatures throughout the load. It takes only a meager investigation, however, to establish (by means of thermocouples distributed in the stack of veneer or lumber) that temperature gradients develop in any load which is under the influence of high-frequency electrical fields, and that these gradients are of such magnitude that they are not masked by differences due to such factors as density and moisture content.

Under the influence of a high-frequency electrical field, a block of "uniform" wood develops heat evenly throughout its mass if no heat losses occur. However, at the same instant that heat appears, dissipation to the surrounding masses of metal and air begins. Temperature gradients develop between the interior of the stack and its surfaces, and between center and edges of any vertical or horizontal plane through the stack. If nothing is done to offset the heat losses, the temperature differentials can be significantly high, often greater than 100°F. but usually less.

A typical, flat, 2-inch thick panel commonly shows temperature differentials of 40°F. between the center level and points ¾ inch from the center (all in the same plane) and, as the surface of the panel is approached, the temperature drops toward that of the impinging mass of metal or air. In a flat panel, the highest temperatures are found in the geographical center of the stack.

A typical, curved, 2-inch thick panel commonly exhibits temperature differentials up to 120°F. The high temperature area, however, is not located in the geographical center between the inner and outer curvatures. Instead the highest temperatures are located but a fractional distance from the inner curve.

This dislocation of the high temperature area is common to curved panels which are moulded to conform to the shape of concentrically placed electrodes. The effect is due to the decrease of the intensity of the electrical field as it progresses from the inner to the outer curve, since the field initiated at the inner curve is distributed over the larger area of the outer curve. Normal heat losses move the area of highest temperature slightly away from the inner curve where the field intensity is the great-

est. Panels which contain a series of flat and curved sections moulded to the form of the electrodes would necessarily have a complicated distribution of temperature differentials.

To offset heat losses, some form of insulation or heat replacement must be attempted. With insulation, the temperature gradient is usually modified so that low temperatures (below the minimum requirement) will develop only in the insulating material which may or may not be the same as the load. Heated electrodes limit the low end of the temperature gradients to a predetermined level and hence are usually preferred. Neither method completely eliminates temperature gradients.

Temperature differentials may often be minimized in the load to the extent that they can be disregarded. When this condition is reached, then the use of an adhesive having a rapid cure at the low end temperature of the gradient is indicated. For high temperature adhesives, a rapid curing in the "cold" area of some loads could be accompanied by charring temperatures in the "hot" area. For some types of constructions complicated setups and modified curing cycles would be in order, if temperature gradients could not be minimized to a reasonable extent.

Glue-line characteristics and costs are often made the only considerations in selecting the adhesive. The problem of selecting this "correct adhesive" is often really the correct application of high-frequency engineering principles.

Mr. L. E. Clark, Jr. (Casein Company of America): My remarks deal primarily with parallel or glue-line heating of urea resins, as they seem to be the widest used combination in the field today.

First, I would like to emphasize one point brought out by Mr. Dimond, namely, the importance of the condition of the stock—particularly that of high-density wood species. You cannot get good bonds with poorly machined joints, and this is particularly true of most automatic clamping edge-gluing equipment. You have to give both the press and the glue a "break" and follow good machining practices. The number of rejects obtained from poorly fitting, warped and twisted stock will balance the cost of a reasonable amount of care in preparing the stock for edge bonding.

Mr. Dimond did not bring out the importance of moisture content of the stock used in edge bonding. This type of gluing is very similar to cold pressing and, if the stock is too dry, the glue-line will dry before it is cured. Another point which is closely related is the matter of the degree of speed at which a urea-formaldehyde joint is heated.

A conventional cold-press urea resin will work well in an R. F. field, but only up to a certain point. It is possible to dry the glue-line before it has cured. You can tell that a glue-line is not cured, if it is still wet, but you cannot necessarily tell that a glue-line is cured because it is dry. The chemical curing of a urea formaldehyde resin requires the presence of moisture to complete itself and, if the moisture is removed too rapidly, it can conceivably dry out and never reach a completely cured stage.

In the general defense of the glue manufacturers, I would like to say that considerable work has been done, and is still being done, on improving resins for radio-frequency curing. Many of the resins being offered today have been especially designed for the purpose. They are not the same as the cold-setting urea resins we went into the game with. However, we are limited to a certain extent by the type of chemical reaction involved and, although it is possible to pour almost unlimited quantities of Btu's into a glue-line, a certain amount of discretion must be observed to insure that the bond obtained by this method is as good as that which can be obtained with the same class of adhesive by other methods.

Close cooperation between the adhesive manufacturer, the R. F. equipment manufacturer, and the mutual customer must be maintained to make certain that one is not "selling the other short," and consequently casting an unfavorable light on the whole method.

Mr. Donald V. Redfern (American Marietta Company): Has a determination of the use requirements of the customer been made in dielectric heating, or is the method being "sold" to the customer involved? Research for the improvement or development of high-frequency equipment and adhesives for any particular job must be evaluated as to its end result—the customer's use requirement. It seems to me that

the question of the customer's wishes and preferences have not been given much consideration; instead they appear to have been overwhelmed by fundamental theories as to why dielectric heating should work, rather than the practical approach required to solve the problem.

Mr. Glen P. Harris (Monsanto Chemical Company): The question has been raised, as to what the situation would be if the manufacturer of the resin adhesives was also the manufacturer of high-frequency equipment, or vice versa. The use of high frequency and resin adhesives is relatively new and it appears to me that the situation is no different than the necessity of cooperation among the tungsten-carbide manufacturers, the tool manufacturers and the consumers of these tools. There must be cooperation between the resin manufacturer, the high-frequency equipment manufacturer, and the user of those products to have the process run efficiently and to continue to make progress in this field.

FOREST PRODUCTS RESEARCH SOCIETY

Application of Dielectric Heating to the Seasoning of Wood*

D. G. Miller

Forest Products Engineer, Forest Products Laboratories, Ottawa, Canada

In this paper the basic principles of radio-frequency dielectric heating as applied to the drying of wood are reviewed. Different experimental seasoning techniques and the problems associated with them are discussed. Exploratory research has shown that dielectric heating has some inherent limitations as a means of drying wood, but for certain applications it facilitates very rapid seasoning.

Introduction

A GREAT deal of thought and experimental work have been devoted to the development of more expeditious methods of drying wood. In recent years considerable publicity has been given to the idea of using radio-frequency dielectric heating for seasoning wood. This method of heating is unique, in that the heat is generated inside the wood itself and therefore the temperature rise is independent of the thermal conductivity of the wood. Because of surface cooling, the interior of wood in a radio-frequency field is often at a higher temperature than the outside. These features of radio-frequency dielectric heating suggest that, apart from economic considerations, it might provide the ideal method of rapidly drying wood from the inside out with a minimum of the usual seasoning defects.

Investigations carried on at the Forest Products Laboratories of Canada at Ottawa during the past year have indicated that, while the application of radio-frequency heating to the seasoning of wood offers interesting possibilities, the technique is somewhat more complex than might at first be thought. These investigations were of an exploratory nature and have not progressed to a stage that would allow any definite conclusions to be made as to the practicability of employing radio-frequency seasoning on an industrial scale. The experiments have, however, provided a clearer understanding of the principles and problems involved and thus have suggested more promising lines of investigation for future research.

Principles of Dielectric Heating

When an insulating or dielectric material such as wood is placed in a rapidly alternating electric field, the molecules of the material are vigorously agitated, first in one and then in the opposite direction. The molecular friction associated with this agitation causes heat to be generated uniformly throughout the material. The more rapidly the field alternates or, in other words, the higher the frequency of the electric field, the lower is the voltage required for a given amount of power. For this reason an electronic device is used to convert the frequency of ordinary electrical power from, say, 60 cycles per second to much higher frequencies, usually between one to 30 million cycles per second. The latter frequencies are known as radio-frequencies, and the electronic device which produces them is called a radio-frequency heating unit. The application of radio-frequency power for heating non-conducting or insulating materials is termed dielectric heating.

An arrangements for applying radio-frequency power for heating wood is shown in Figure 1. The radio-frequency heating unit is connected to metal plates, usually called electrodes, and the wood to be heated is placed between the electrodes. The electrode system shown in Figure 1 is the type commonly used for wood-bonding applications. In dealing with drying applications, provision is usually made for the escape of moisture from the wood by introduc-

* Contribution from the Forest Products Laboratories of Canada, Mines, Forests and Scientific Services Branch, Department of Mines and Resources, Ottawa.

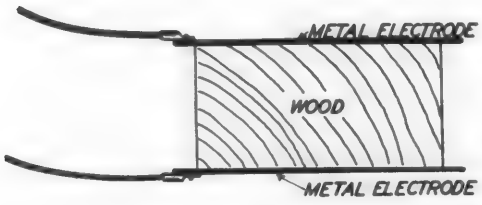


Fig. 1.

ing an air gap between the electrodes and the wood, as shown in Figure 2.

The radio-frequency power supplied to a dielectric load is expressed by the following simplified relationship:

$$P = \frac{1.415 \times 10^{-6} \cdot f \cdot E^2 \cdot K \cdot \cos\theta}{d^2}$$

where

P = power supplied in watts per cubic inch of material
f = frequency of power in millions of cycles per second
E = effective voltage across material
K = dielectric constant of the material
$\cos\theta$ = power factor of material
d = thickness of material in inches.

This expression is introduced to show that if the voltage, frequency, and thickness are constant, the power supplied to the material varies as the product of its dielectric constant (K) and its power factor ($\cos\theta$). This product is known as the "dielectric loss factor" of the material and it varies considerably for different materials. In the case of wood, the dielectric loss factor is affected by such variables as the wood species, temperature, frequency, and, especially, by the moisture content of the wood. The dielectric loss factor increases with the moisture content of the wood, and it follows therefore that regions of high moisture content receive more power and develop greater heat.

When a piece of clear wood of uniform moisture content is heated by radio-frequency power, the energy is absorbed uniformly throughout the wood. However, if the piece is exposed to room conditions, surface cooling of the wood will take place and we have the interesting situation of the interior being at a higher temperature than the outside, suggesting that heating is proceeding from the inside out.

The ideal method of drying a piece of wood is, of course, to apply heat at the center of the piece and keep the surfaces cool and moist. The moisture would move in the direction of the temperature gradient from the center to the outside and, because the surfaces are moist, the usual problems of checking, casehardening, and honeycombing would be eliminated. On first consideration it appears that in dielectric heating we have this ideal method of drying wood: it can heat wood rapidly, there is a temperature gradient from hot in the interior to cool on the outside, and the wet spots receive more heat.

Boiling Method

The work of early investigators tended to substantiate this theory, and first reports on experimental work were enthusiastic. Employing electrode systems similar to that shown in Figure 2, it was found that small wood specimens could be dried from a high moisture content in a few minutes and that the quality of the seasoning was usually good. A high power concentration of 15 to 20 watts of radio-frequency power per cubic inch of wood was used and often the moisture was driven out of the wood as steam. This technique is sometimes referred to as the "boiling" method and it can be used successfully on small pieces of

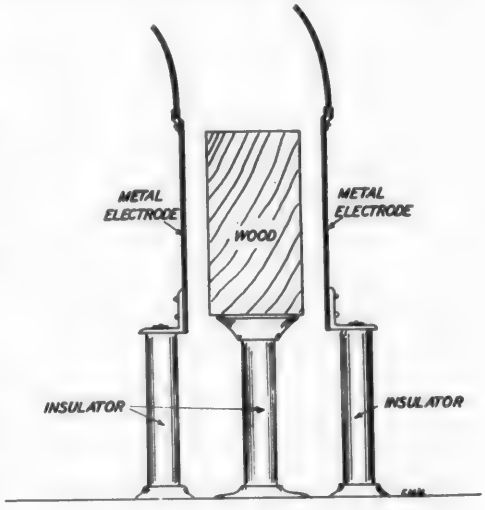


Fig. 2.

wood. The internal heat appears to create a vapor pressure which accelerates the movement of the moisture from the center to the surface. The surfaces of the wood remain moist until the drying is almost complete and the internal temperature does not rise much above 212° F. until the wood is dry. Moisture measurements taken at different stages during the drying show a definite gradient of increasing moisture content from the center to the outside; in other words the wood dries from the inside out. It appeared that, although seasoning wood by dielectric heating was a rather expensive method, the process was theoretically sound.

However, when an attempt is made to use the boiling technique on larger specimens with a minimum cross-sectional dimension of two inches or more, new problems are met. The movement of the moisture through the wood is slower because of the greater distance. The vapor pressure generated inside the wood is not readily relieved and, in the case of hardwood specimens, will actually explode the wood, or at least split it. A further difficulty arises in the case of softwood specimens. There is a tendency for overheating to take place at the center and at points where there are knots or pitch pockets, causing charring or burning. In the small specimens the escape of the moisture produces an effect similar to that occurring with a wet-bulb thermometer and the temperature does not rise above 212° F. In the larger specimens, however, the moisture cannot escape as readily and the temperature continues to increase sufficiently to cause charring.

Temperature Gradient Method

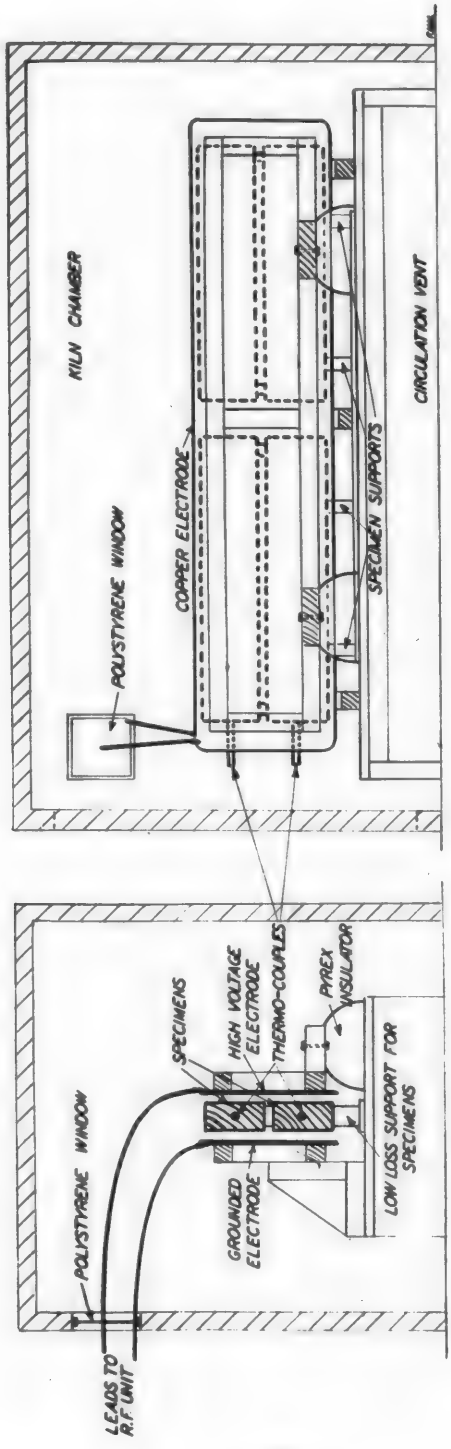
It might be thought that these difficulties could be overcome by reducing and controlling the power so as to maintain the temperature in the center of the specimen at some value below 212° F. A temperature gradient would be created which should cause the moisture to move from the interior to the outside as in the ideal drying set-up. However, when tests are made with this technique the results are not entirely ideal. The very seasoning flaws we had hoped to eliminate, surface set, casehardening, honeycombing, etc., are often very evident. The explanation of this anomaly is not difficult.

As mentioned previously, when a piece of wood is heated by radio-frequency power, the temperature rise is not uniform through the cross-section. The temperature at the surface of the wood remains near that of the surrounding atmosphere, while the temperature at the center begins to rise. On the other hand, the energy is supplied fairly uniformly throughout the cross-section and the outside layers of wood receive about the same number of heat units per cubic inch as the wood at the interior. This heat is available to evaporate the moisture in the surface layers which, because it is near the surface, can readily escape into the surrounding atmosphere. Consequently the moisture in the outside layers of wood is evaporated faster than moisture can move out from the interior and the result is excessive surface drying.

It will be appreciated that this difficulty does not arise when drying small specimens with a high concentration of radio-frequency power, because the moisture is forced the short distance from the interior to the surface so rapidly that the outside layers of wood are always damp until the drying is completed.

Tests on White Pine Specimens

Some improvement can be obtained by surrounding the drying setup with an atmosphere of low temperature and high relative humidity, so as to retard this excessive surface drying and allow the moisture in the interior to move out to the surface. This technique was investigated at the Forest Products Laboratories of Canada, using the set-up shown in Figure 3. An electrode system which would accommodate four specimens, each 3 by 6 by 36 inches was installed in a small kiln. The leads from the radio-frequency heating unit were connected to the electrodes through a small polystyrene window mounted in the side of the kiln. Thermocouples were inserted in the centers of the ends of the two front specimens in order to measure the internal wood temperatures. Since the main point of interest was the quality of the seasoning, the procedure consisted of drying one set of four specimens by dielectric heating and of drying a matched set in a kiln using a standard kiln-drying schedule, for the purpose of comparing the quality of the seasoning.



ELECTRODE SYSTEM USED FOR DRYING TESTS ON WHITE PINE AND BEECH SPECIMENS

Fig. 3.

In tests on green specimens of white pine, the kiln atmosphere was maintained at 85° F. with a relative humidity of 95 percent. The temperature at the center of the specimens was maintained at between 190° F. and 195° F. The specimens were dried from an average moisture content of 110 percent to an average of 7 percent in approximately 120 hours. The specimens that were kiln dried had an average initial moisture content of 110 percent and were dried to 7 percent in approximately 720 hours. A typical drying curve for specimens dried by dielectric heating is shown in Figure 4. The quality of the dielectric seasoning was

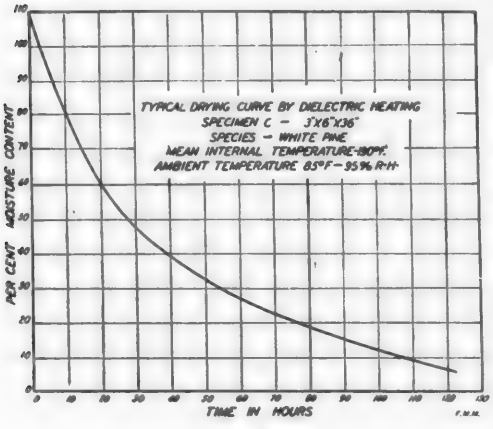

TYPICAL DRYING CURVE BY DIELECTRIC HEATING
SPECIMEN C — 3"X6"X36"
SPECIES — WHITE PINE
MEAN INTERNAL TEMPERATURE-190°F.
AMBIENT TEMPERATURE 85°F—95% R.H.
PER CENT MOISTURE CONTENT
TIME IN HOURS

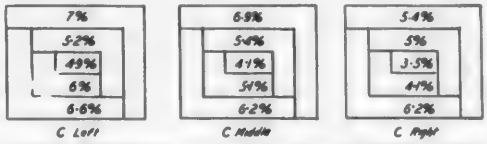
Fig. 4.

good. Moisture measurements showed a gradient of increasing moisture content from the interior to the outside in the specimens dried by dielectric seasoning. Typical moisture gradient sections produced by radio-frequency heating are shown in Figure 5, and for comparison some moisture gradient sections of kiln-dried specimens are included. Among the specimens which were dried by dielectric heating, there were some with a higher original moisture content than others. It was interesting to find that those with the higher moisture content had a higher internal temperature at the start of the drying and more rapid drying took place in those specimens until their moisture contents were reduced to the average of all specimens. From this work it appeared that by means of dielectric heating and an unheated high-humidity chamber, thick specimens of pervious woods such as white pine can be successfully seasoned in a fraction of the time required for normal kiln drying. A temperature gradient is established in addition to the usual moisture gradient, and this temperature gradient accelerates the movement of moisture through the wood cells. The high humidity atmosphere sufficiently retards the tendency for excessive surface drying to allow the moisture to diffuse outward from the center. This work also confirmed the theory that radio-frequency power selectively heats those portions of the wood with a higher moisture content, thus automatically adjusting the drying rate to produce a uniform moisture content.

It must be emphasized that these remarks are made with reference to the theory of dielectric seasoning and it is not intended to imply that it is commercially feasible to dry green pervious wood by dielectric heating. More rapid and better quality drying of wood may be possible by dielectric heating, but the economics of the method become doubtful when the evaporation of large amounts of water are involved.

Tests on Beech Specimens

Using the same experimental set-up and procedure, further tests have been made with similar specimens of Canadian beech. This species was selected because it is an impervious wood which is notoriously difficult to season in thicknesses much over an inch. In the first tests the surrounding atmosphere was controlled at 85° F. and 95 percent relative



TYPICAL MOISTURE GRADIENT SECTIONS FROM A SPECIMEN DRIED BY DIELECTRIC HEATING

TYPICAL MOISTURE GRADIENT SECTIONS FROM A KILN-DRIED SPECIMEN

Fig. 5.

humidity, and the internal wood temperature was maintained at approximately 160° F. The result was severe casehardening, honeycombing, and collapse. It appeared that, in spite of the high ambient humidity, the uniform heating of the specimen caused excessive surface drying. The interior moisture could not move up fast enough to replace that evaporated from the surface. This severe surface drying was at first puzzling, in view of the surrounding very high humidity, until it was realized that the surface of the wood, although at a much lower temperature than the interior wood, was still at a higher temperature relative to the kiln atmosphere. Therefore, the relative humidity at the surface of the wood was not 95 percent as intended, but somewhat lower. Further tests were made, using progressively milder schedules, and the results improved but were still far from satisfactory. It was found that the checking continued until the average moisture content dropped below approximately 30 percent, then the checking ceased and the checks began to close up. At this stage, the power and the wood temperature could be considerably increased without further damage and consequently fairly rapid drying was possible.

Based on the experience gained from these tests, it appears doubtful that there would be much advantage in drying green or very wet impervious hardwoods by dielectric heating. In the case of these woods, the rate of drying is definitely limited to the rate that free moisture can diffuse through the wood. Radio-frequency heating supplies heat uniformly through the cross-section of the wood and therefore causes the moisture in the outside layers to evaporate faster than the free moisture can diffuse out from the center. If the surrounding atmosphere has a high humidity, this action is retarded, but not sufficiently so until the moisture content is below the fiber-saturation point. The closing of the checks when the moisture content was below 30 percent indicated that drying was beginning to take place in the interior, forcing moisture to the outside. In other words, drying from the inside out does take place after the moisture content is below the fiber-saturation point. At this stage, surface drying is greatly reduced and a high internal temperature can be used which produces rapid drying, much more rapid than is possible in the final stages of kiln drying. It appears, therefore, that while radio-frequency heating offers little, if any, advantage over kiln drying for the preliminary seasoning of green or very wet hardwoods, it may provide an expeditious method for final drying of air-dried or partially seasoned hardwood lumber. The amount of moisture which must be evaporated for the final drying of wood is relatively small and this fact would tend to improve the economics of the method and to simplify the problems of electrode design.

Summary and Conclusion

As mentioned at the beginning of this paper, the research work which has been done on the application of dielectric heating to the seasoning of wood has been only sufficient to provide a better understanding of the principles involved. We have found that dielectric heating is not, as might be thought, the theoretically ideal method of drying wood, but that it does have some unique features which warrant further investigation. Using a high power concentration, it will rapidly drive the moisture out of small wood specimens. This boiling technique is, however, unsuitable for drying larger pieces of wood because the moisture cannot readily escape and consequently the wood is ruptured or is overheated at the center. The temperature gradient method is more suitable for drying thick lumber but there is a tendency toward excessive surface drying, particularly in the case of impervious woods. A high ambient humidity will control the surface drying of green pervious species and these woods can be successfully dried in a fraction of the time required for kiln drying. The surface drying of impervious species can be controlled by a high surrounding humidity if the moisture content is below the fiber-saturation point. Under these conditions very rapid drying is possible. This appears to be one of the most promising avenues for future research. Dielectric heating may provide an expeditious method for the final seasoning of high-grade hardwoods. The economics of this application are more encourag-

ing than in the case of drying green, pervious woods because the amount of moisture to be evaporated for final drying operations is relatively small.

These discussions are based on small-scale laboratory tests which were primarily concerned with the theory of dielectric seasoning. It is doubtful if the type of electrode system used for experimental work would be suitable for industrial drying operations. The development of electrode systems capable of handling normal kiln charges, the economics of dielectric seasoning, and the preparation of drying schedules are matters which should form the objectives of further research on the application of dielectric heating to the seasoning of wood.

Discussion

Mr. Raymond C. Rietz (U. S. Forest Products Laboratory): Very little information has been published on the drying of wood by dielectric heating. Therefore Mr. Miller's report is particularly welcome at this time. The wood-producing and wood-using industries are always interested in ways and means of reducing drying costs and, to many people, high-frequency heating seemed like one of the ways of accomplishing this desired result. Our own limited research confirms Mr. Miller's findings, namely, that factors other than the manner in which heat is applied for the water evaporating process are influential. The physical properties of wood which control the diffusion of moisture govern the rate at which the wood can be dried without seasoning degrade. To date we know of no heat source and method of application which would seem to modify this basic theory.

As Mr. Miller has pointed out, economies determine whether dielectric heating or, in fact, any other special method of heating wood can be employed. In this respect the following analysis is of interest, as regards the cost of drying lumber by high-frequency dielectric heating. The computation is based upon a daily output of 10,000 board feet per 24 hours and upon the following assumptions:

1. Weight of wood, oven dry, per cubic foot	43 pounds
2. Initial moisture content	63 percent
3. Final moisture content	8 percent
4. Moisture to be removed	60 percent
5. Volume of 1,000 feet, board measure	83.3 cubic feet
6. Operating days per year	300
7. Output of generators	365 kw.
8. Output of generators per hour	1,250,000 Btu.
9. Assumed cost of generators	$65,000
10. Cost of power tubes (each)	$1,125
11. Estimated life of power tubes (1,000 hours guaranteed; two required)	5,000 hours
12. Cost of rectifier tubes (each)—6 required	$190
13. Estimated life of rectifier tubes	3,000 hours

The investment costs in equipment are estimated as follows:

1. Total investment in generators only (output of 365 kilowatts)		$65,000
2. Average annual interest charge for 10 years	$ 1,432	
3. Annual liquidation charge	6,500	
4. Annual charge for power tubes 2 x 1.44 x 1,125 =	3,240	
5. Annual charge for rectifier tubes 6 x 2.4 x 190 =	2,736	
6. Total average annual charge for interest capital, liquidation, and tubes	$13,908	
7. Investment charges per day—$\frac{13,908}{300}$ =		$46.36
8. Investment charges per 1,000 feet, board measure		4.64

The cost of electrical energy is estimated as follows:

9. Btu. required to heat 10,000 board feet of wood and water to boiling point from 72° F. = 140 x 43 x 83.3 x .336 x 10) + (140 x 43 x .68 x 83.3 x 10) = 1,685,000 + 3,410,000 =	5,095,000
10. Btu. required to evaporate excess water from 10,000 board feet = 971 x 43 x 83.3 x .60 x 10 =	20,868,150
11. Total heat requirements, Btu.	25,963,150
12. Calculated power requirements $\frac{25,963,150}{3,412}$ =	7,609.1 kw.-hr.
13. Calculated power requirements per 1,000 board feet	761 kw.-hr.
14. Since the input is at least twice the output, the total power requirement per 1,000 board feet is	1,522 kw.-hr.
15. If the cost of electricity is 1 cent per kw.-hr., the cost for power per 1,000 board feet would be	$15.22

The total cost for drying this volume of wood is then $4.64 for equipment plus $15.22 for electrical energy, or $19.86 per 1,000 board feet. This estimate of approximately $20.00

per 1,000 board feet does not include housing, mechanical equipment for handling the lumber, heat losses, labor, or the salary of a technically skilled operator to adjust the electrical equipment and properly control the drying of the lumber. It is obvious, therefore, that high-frequency dielectric heating can only be considered at this time for the drying of specialty items of wood that have sufficiently high value to absorb these high drying costs.

Prof. E. L. Ellis (University of Idaho): Mr. Rietz, in his analysis, has used an electrical energy cost based on a price of approximately one cent per kw. hr. In the West, where industrial users can often purchase electricity for as little as two or three mills per kw., this might have a marked bearing on the possible application of high frequency to wood seasoning. A reduction of one-third to one-fifth in energy costs would certainly be reflected by a greater economy in an operation of this type.

I should like to ask Mr. Miller about the possibility of producing a small capacity high-frequency apparatus specifically designed to measure moisture content of wood rapidly. It is my thought that an extremely rapid means of measuring moisture content would have application in certain industries, particularly if such a means of measurement would be relatively inexpensive and suited for use by untrained operators. I feel that there is a place for a rapid moisture determining apparatus of this type, possibly in drying or for check determinations in woodworking plants where moisture content of stock is rather critical; an example would be the Douglas fir plywood industry, where the moisture content of the veneers is significant.

Mr. Miller: Although I have often considered the use of dielectric heating for moisture-content determinations, I have never carried out an investigation on that specific application. Dielectric heating would certainly expedite the drying of moisture specimens, but the control of wood temperatures would be more difficult and it would be necessary to develop some method of automatic control to prevent overheating of the specimens. I am confident that a special radio-frequency drying unit could be designed for this purpose, but I am a little doubtful if the time saving over conventional drying ovens would justify the expense of a dielectric-heating device which would probably cost at least a hundred dollars.

Mr. Glen P. Harris (Monsanto Chemical Company): With respect to the possibilities of using the technique of drying wood for moisture-content determinations, I should like to say that such an instrument has been demonstrated in the New England states (successfully, I believe). Although I do not have the manufacturers name, at the moment, I can forward it to those interested.

Mr. John M. Yavorsky (W. T. LaRose and Associates): Our efforts in the dielectric drying of lumber have brought results quite similar to those obtained by Mr. Miller. We have been able to dry some of the more previous species, such as eastern pine, quite successfully. Sample boards 1 x 5 by 54 in. have been dried from 70–80 percent down to 10–15 percent moisture content in from two to four hours without deleterious effect on the wood structure. However, a production set-up to dry such lumber at the rate of 1,000 board feet per hour would require a 700 kw. generator, since green lumber on the average contains one ton of water per 1,000 feet. The possibility of supplementing a present kiln set-up with electronic drying seems to me to be a very logical method of attack. The removal of the "free" water can easily be accomplished wth present drying processes. However, once the fiber-saturation point has been reached, the removal of the "bound" water becomes much more difficult. It is at this point, as Mr. Miller has indicated, that dielectric heating may be most economically applied and the best results obtained.

Prof. A. H. Bishop (New York State College of Forestry): I agree with Mr. Miller in his statement that, at the present time, dielectric seasoning is not economically feasible. We have successfully dried 12/4 hard maple in individual pieces 8 in. wide by 24 in. long, but the cost is entirely too high. Furthermore, temperatures within the wood were not uniform, but higher in the center than nearer the surface. Temperature gradient could be altered somewhat by frequency, but we also had the effect of heat of emissivity from the surface.

Mr. M. E. Dunlap (U. S. Forest Products Laboratory): The question is sometimes raised about preheating lumber to be kiln dried, in

order to gain time. This is not a practical procedure since lumber can be brought up to stating temperature in one or two hours' time, while a kiln run may extend from 100 to 700 hours or more; it is obvious that a preliminary heating period would only be a small fraction of the time necessary for drying a kiln load of lumber and is not important. Further, it would be necessary to do the preliminary heating after the lumber had been piled on trucks ready to be placed in the kiln. This would require the rapid heating of a considerable amount of wood and water in a short time, a wide spacing of electrodes, and voltages greater than generators are capable of producing. The maximum voltage possible with present generators is about 17,000.

The suggestion has been made that dielectric heating be applied to moisture-content determinations. Such an application would require careful controls to prevent overheating the samples and thereby distilling off some of the wood substance that would be counted as moisture. Usually moisture samples are small and do not require long periods to reach the oven temperature. However, for acurate determinations, a number of hours usually elapse before constant weight is reached. Approximations could be obtained after short periods of heating.

One hundred and twenty hours was required to dry a 3- by 6-inch white pine bolt described in Mr. Miller's paper. This time is one-sixth of that required by kiln drying, but 120 hours is a long time to tie up a very expensive high-frequency generator. This means that the drying equipment would have to be very large if a sizeable production is to be maintained.

Mr. G. W. Kuehn (American Creosoting Company): We have been experimenting with high frequency to condition crossties and thick timbers for pressure treatment, with unexpectedly good results, continuing the work outlined by Mr. Paul D. Zottu before this Society on October 31, 1947. This involves removal of very small amounts of moisture and heating timber throughout, to facilitate preservative penetration. Results are being obtained too rapidly to report now, but are good.

Mr. William J. Baker (Oregon Forest Products Laboratory): Virtually all of us have encountered the universal problems arising from residual internal stresses in lumber and other wood products that have not been given a conditioning treatment at the termination of either air seasoning or kiln drying. This treatment to relieve internal stresses may require only a few hours for thin softwood material, but it may take a couple of days or so for thick, dense hardwoods. Would Mr. Miller care to comment on the theoretical aspects of relieving these stresses by the application of dielectric heating?

Mr. Miller: Mr. Baker's suggestion that dielectric heating might be used for relieving residual internal stress in lumber is a very interesting one. From an academic viewpoint at least, the idea has merit because we have established that dielectric heating will assist in the redistribution of moisture in lumber and this redistribution combined with heat might be sufficient to releive the internal stresses.

I have not investigated this point experimentally but I hope that some work can be done on it in the near future by myself and other investigators. I feel that it would be necessary to surround the electrode system with an atmosphere of high humidity or else the stress condition might be aggravated. This means that the facilities for the conventional steaming technique would be required, plus the dielectric heating apparatus, and again the cost might be prohibitive for commercial use.

TECHNICAL SESSION VIII

Wednesday, March 24, 1948, 1:00 P. M.

General Subject: Dielectric Heating (continued)

Chairman: Archibald C. Knauss, Utilization Technologist, Pacific Northwest Forest Experiment Station, Portland, Oregon *(Chairman, Pacific Northwest Section, FPRS)*

Recorder: Arthur L. Mottet, Research Engineer, Long–Bell Lumber Company, Longview, Washington *(Vice-Chairman, Pacific Northwest Section, FPRS)*

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The Technology of the Glue Line in Electronic Edge-Gluing of Lumber

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WITHIN the past two years there has been a rapid growth in the application of high-speed, lumber edge-gluing presses. These, synchronized with electronic machines, swiftly cure the glue lines composed of resin adhesives which are designed to draw a large amount of power without arcing or burning. The new process has found ready acceptance by the woodworking industry, because of the speed and steady flow of production which it offers.

As is often the case with new processes, however, some plants are not always able to obtain all the advantages which are available. This is especially true of a process such as this, which has been ingeniously simplified to push-button control without equal regard, occasionally, for the material being processed. Sometimes slight changes are necessary in the selection, handling, and preparation of the stock, in order to permit the electronic edge-gluing machine to function properly. When such changes are not made, an alarming amount of reject stock may be produced and the installation may be considered misfit when actually it is misused.

It has been observed that, when proper adjustments are made so that good stock emerges from the edge-gluer, this machine will not only improve production but also the product. For example, it is known that lumber with high or widely varying moisture content should not be used in most built-up constructions. In ordinary cold-clamp work, there is no way of preventing its appearance in the finished article once the wet lumber has been admitted into production. With an electronic edge-gluer in the operation, the wet lumber will be rejected at that point, because it will refuse to glue if the machine has been set for a certain bonding cycle on properly dried stock. Similarly, mixed species and densities, excessively thick or thin boards, and poorly edged lumber will be revealed and eliminated; *provided* the operators are sufficiently familiar with cause and effect to recognize symptoms and institute the remedies.

Viewed in this manner, the electronic edge-gluing machine may be considered not only an instrument for more efficient production, but also as a mechanical inspector for controlling the quality of the product to a desired standard. However, before either of these objectives can be realized, it is necessary to understand the function of a large number of factors which influence the operation.

This paper will discuss in some detail the smallest, but perhaps most important part of the problem—the glue line and the bond. Since this is the link we are trying to fashion, the success or failure of the job is measured here. Many of the factors that enter into the operation register their effects on the glue line. In order to be able to observe these effects and deduce what has taken place, a general knowledge of the mechanics of adhesion is desirable as well as an understanding of how the bond is affected by such variables as species of wood, moisture content of wood, nature of surfaces, bonding pressure, character of glue, temperature, etc.

Much of the information contained herein has been gleaned from observations of a number of installations which have passed through the adaptation stage to successful production. Since knowledge in this field is still evolving, the behavior of all the factors may not yet be well enough established to predict what may happen in all cases. What is presented here should be considered only as a compilation of current information, given for the purpose of

aiding the new user and also for eliciting or arousing comment from old users who are in a position to add to the story.

Before proceeding to the consideration of the various factors of the edge-gluing operation, let us first see what the adhesive itself is trying to do as it forms a bond. We can then better visualize and appreciate how the factors affect each action the adhesive must perform before a strong, durable bond can be made.

Mechanics of Adhesion

The bond between two wood surfaces may be considered to consist of five distinct and equally important phases:

1. The wood and its surface on one side.
2. The association between wood and glue on one interface.
3. The glue film itself.
4. The association between glue and wood on the other interface.
5. The wood and its surface on the other side.

A highly magnified end-grain section of a joint (Figure 1) will illustrate the relationship of the five phases.

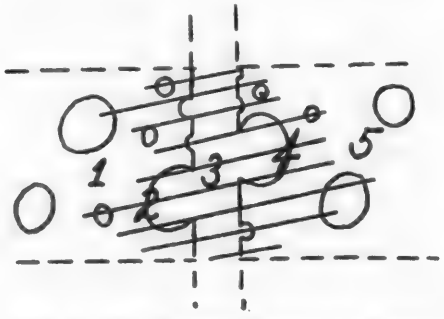

Fig. 1.—Highly magnified end-grain section of a joint.

Assuming that each phase is responsible for one link in the completed bond, failure at any point will obviously result in failure of the joint. This is a fundamental precept and must be continually borne in mind in interpreting all glue-line observations. The practice, especially among untrained personnel, of diagnosing failures based only upon 3, the glue film itself, will too often lead to erroneous conclusions. The glue film is seldom the weakest of the five links with resin glues (unextended with flour), except when, due to overpenetration or excessive squeeze-out, it is not present. The weakest link is most likely to occur at 2 and 4, the interfaces between wood and glue, and it is here that many factors insidiously operate to confuse the problem.

In the formation of a bond between two wood surfaces, an adhesive must perform these basic actions:

1. Penetrate the wood cavities.
2. Wet the wood substance, *i.e.*, grip.
3. Fuse to a strong, insoluble film.

The degree to which all three of these actions has occurred determines the quality of the bond with any particular adhesive, and each can be readily observed with some practice. They are the keys which lead to the deduction of the particular factors that were operative at the time the adhesive was cured.

In this and subsequent usage, the terms "adhesive" and "glue" refer to resin adhesives, such as urea-formaldehyde or resorcinol-formaldehyde.

Penetration of the adhesive, the first of the three actions, is perhaps the most important, not only because it influences the other two, but because it is itself largely influenced by operating conditions. Insufficient penetration will result in a shallow, weak bond. Too much penetration, as may occur on open-grained woods, will give a starved glue line which, as previously indicated, destroys the center link, 3, in the bond. Since only one surface of a joint generally is spread with glue, penetration into the unspread surface is accomplished only by actual contact of both surfaces *while the glue is fluid*. This leads to an extremely important observation, because it may reveal whether the joint was properly drawn up in the press, whether the surfaces were poorly machined, or whether the glue had precured. If transfer and penetration to the unspread surface have failed to occur on long areas of the joint, then it was not drawn up properly due either to obstructions in the press or miscut edges. If the unspread surface is spotted with glue, it is an indication of poor machining since transfer has occurred only on the high spots. Precured glue will have a rough appearance on the surface on

which it was spread and no transfer to the opposite surface.

Wetting of the wood substance by the adhesive, the second action, involves the chemical attraction of wood for the adhesive molecule and is thought to be the basis for adhesion itself. It is responsible in large part for the durability of a bond with a given adhesive, because it influences the number of infinitesimal bonds that may be formed between glue and wood. Wetting is in part a property of the adhesive, in part an operating variable, and in part a property of the wood surface. Most resin adhesives have a great affinity for wood in their original mixed form. However, this affinity gradually diminishes as condensation, later defined, progresses; sometimes, particularly in cold-setting adhesives, it may be decreased to such an extent during a long pot life and assembly time as to prevent the proper transfer and wetting of the mating unspread surfaces.

Wetting is also inhibited in some cases by the wood surface. For instance, burning or burnishing by dull knives, worn sandpaper, or hot platens may completely destroy the inherent attraction wood may have for glue. Some species of wood, such as teak, cedar, and gum heartwood, are especially unreceptive to certain adhesives, and very little wetting may occur.

The identification of poor wetting is often difficult without some magnification. On fairly coarse-grained woods, however, the imprint of the opposite surface on the glue line of a broken joint may be clearly seen and is evidence that no wetting has occurred.

The fusing of the glue to a strong, insoluble mass or film, the third action, is a property of the adhesive and is achieved through condensation. Condensation and polymerization are chemical terms describing the manner in which molecules grow. They are often used indiscriminately to denote curing of adhesives. Condensation is the correct term for resin adhesives since it defines a chemical reaction in which two or more molecules combine with the separation of water or some other simple substance. All thermo-setting resin glues have this property at varying speeds and temperatures and can be depended upon to perform this action when handled according to the manufacturer's instructions. The formation of a film, however, is partly an operating variable as well as a characteristic of the grade of the glue. Such factors as amount of spread, porosity of the wood, pressure, and consistency of the mixed glue, all have a bearing on the quality of the film that is finally produced at the glue line.

The strength and insolubility of the cured glue line may also be affected by the rate at which the temperature is increased. All of the factors that enter into this possibility are not clearly understood. They will be discussed later in the paper.

Action of Resin Glues Under External Heat and Electronic Heat

Most of the resin glues used in electronic edge-gluing are of the "cold setting" type; *i.e.,* they will cure at room temperature in two to eight hours depending upon their catalysis. When external heat is applied to a liquid glue of this type, three things happen:

1. Rate of condensation (curing) increases tremendously.
2. The consistency of the glue decreases momentarily.
3. Moisture evaporates from the glue.

The increased rate of curing under heat is one reason why these glues are uniquely suited to electronic gluing. They permit the very short press cycles which make the operation feasible. On the other hand, the decrease in consistency of the glue is a disadvantage, because this encourages over-penetration of the adhesive with consequent likelihood of starving the glue line. Furthermore, the apparent loss of "body" in the glue diminishes any gap-filling properties it may have had and explains why more accurate machining is necessary. There is some reason to assume that the higher temperature of the adhesive just prior to curing enhances its wetting properties and should therefore improve durability of the bond. Interactions between loss of "body" and improved wetting are obscure.

When high-frequency heat is applied to these glues, the same things occur, except that the temperature rise is practically instantaneous and the evaporation of moisture is much faster. Whether or not the faster evaporation of water

from the glue is detrimental to its complete cure has not yet been fully investigated. However, since water is the medium which facilitates the orientation and chemical build-up of the resin molecules, its removal, before this has been accomplished, can conceivably subtract from the ultimate strength and durability of the bond. Some restraint should therefore be exercised in the speed with which resin glues are cured. Heating cycles of less than 15 or 20 seconds should be discouraged until more information is available.

However, the removal of water from the glue line when electronic heating is used results in one of the important advantages of the operation. Panels may be planed and processed shortly after gluing without fear of sunken joints. Some elapse of time between gluing and planing is desirable to allow the hardening of the glue squeeze-out and to develop the full strength of the bond, since complete cure is not always obtained in the press.

One of the indications of too rapid moisture loss from the glue line is the frothy appearance of the glue on broken joint surfaces. Sometimes this will have a grainy character. Neither condition is conducive to good bonding. Unfortunately, however, this is only the least effect of too rapid moisture dispersal. More serious is the creation of steam pressure at the glue line which forces the glue from the joint and produces a starved condition. In extreme cases, the steam pressure may become so great that, together with its plasticizing action on wood substance, it causes the wood in the vicinity of the joint to collapse. This condition may often be accompanied by some charring of the wood.

Arcing and burning have been greatly reduced or controlled in this type of work. Arcing, which is generally caused by a voltage breakdown in the glue, has been largely eliminated by the use of less conductive glues and higher frequencies which permit lower voltages. Burning, however, which seems to be caused by a combination of the species of wood, the glue, and concentration of power in certain glue lines, often requires individual, on-the-job adaptations for consistent control. Some species, such as birch and maple, rarely burn with any glue. In other species, such as white oak, the burning may be reduced by changes in the glue formula. Still other species, mahogany for example, may require some changes in the method of applying power as well as changes in the formula.

The Electronic Edge-Gluing Operation

The electronic edge-gluing operation is similar in many respects to the clamp method of edge-gluing. The stock is prepared in the same manner, spread with glue, often in the same roll spreaders, and the finished panels may continue through the same processing. However, aside from the manner of applying pressure and curing the glue, there are several important deviations which are either vital to the process or consequent to it.

First, is the necessity for a little more care in the selection of stock, its moisture content, its preparation and its easy accessibility to the operators of the machine. These are the main factors that often spell the difference between success or failure. As obvious as it may appear, some installations have been condemned for failure to produce, when the cause was inability of the operators to handle the stock as efficiently as was necessary.

The importance of proper preparation of the stock cannot be over-emphasized. Edges must be flat and true, or all the five links of the bond cannot be made. Glue has no dependable property that permits it to bridge gaps and inequalities and produce a strong, durable bond. This is particularly true, in their present state of development, of glues which are cured with high frequency. That is why it is more necessary to have better machining and, consequently, is also why this type of set-up will actually improve products. Improperly machined stock often will not get too far past the edge-gluer.

In order to understand the effect of moisture in the stock, it is necessary to visualize the electrical nature of the problem. Most batch-type presses have continuous electrodes on the top and bottom of the panel. The glue lines touch and connect the two electrodes, which actually are plates of a huge condenser. (Figure 2)

The dielectric properties of the wood and glue influence the heat that is generated by the high-frequency field imposed between the two

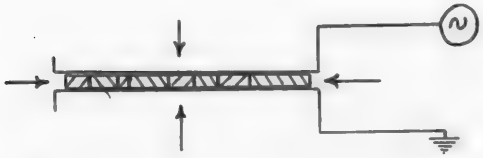

Fig. 2.—Edge-jointed assembly between electrodes.

plates. Moisture, in turn, influences the dielectric properties of wood. Variations in moisture will therefore cause variations in heating; and variations in heating obviously cause variations in the degree to which the glue is cured. This is the second reason why this type of operation will improve products. Stock with excessively high or varying moisture content will fail to glue consistently and will have to be removed from production.

Variations in density or species may produce the same effect as moisture, since the dielectric properties vary significantly. Cottonwood, for instance, will not behave the same as oak. Glue lines in cottonwood can be set much more rapidly than in oak. This is due in part to the lower degree of cure that is necessary to reach the strength of cottonwood, and in part to the dielectric properties of the latter which cause the production of more heat in the glue line. As a general rule, the time required to cure glue lines will vary as the density of the wood.

In the usual operation of batch-type electronic edge-gluers, the panel is spread with glue and laid up as in other operations. A sequence of actions is then started by placing the panel between the electrodes. First the electrodes are brought to bear on the panel with a load of 5 to 10 psi. This prevents buckling, while side pressure, which comes on next, is raised to the maximum of 200 to 300 psi. Top pressure is then momentarily relieved to prevent frictional forces on the surface from decreasing the effectiveness of the side pressure. When full pressure is on, the high-frequency generator automatically begins its heating cycle of 15 to 60 seconds, after which the press opens and the finished panel is removed by the injection of the next panel.

Since no buckling can occur in the press, panels emerge relatively flat and no extra planing is necessary to remove bulges. Furthermore, since the panel is assembled horizontally on a flat surface, all irregularities due to thick and thin boards occur only on one side of the panel, leaving the other side free from such unevenness, and ready for a finish cut on the planer. These are important advantages. However, like all good things, they have a price.

Buckling is caused by lack of parallelism of the joint edges as the panel lies flat with edge pressure applied. It is actually a shift, which is attempting to bring the joint edges parallel with each other. If this shift is prevented by top pressure, open joints are bound to occur on one side or the other of a panel, when edges are jointed out of square with the face. Quite often, with low-density woods, the side pressure is sufficient to close this type of gap, due to compression of the wood at the high edge. However, this cannot be considered good practice for two reasons. First, spring-back from compression may later warp the entire panel and, second, progressive closing of a joint in that manner may squeeze too much glue from the joint and also prevent the build-up of pressure on the glue which is necessary to force it into the wood cavities.

The price for obtaining unevenness all on one side of the board is a longer press cycle. Mixed thick and thin boards require a longer heating period than thicker boards alone. This is because, in the mixture, some glue lines do not make contact with the electrode. The series air-gap thus created decreases the power in that glue line. The press cycle should therefore be determined with loads comprising the greatest difference in thickness of boards.

The art of electrode design is rapidly overcoming the effects of certain variations in stock. Strip electrodes or stray-field electrodes and air-gap electrodes are designed to reduce variations. Automatic tuning is also a major development in the reduction of variables.

Preparation of the Stock

As previously indicated, preparation of stock is one of the most important factors in the successful operation of edge-gluing equipment. This factor covers a number of points, some of which have already been discussed:

1. Density of wood

Variations in density of the wood cause variations in power distribution. Woods such as mahogany for instance, whose density varies

widely, may give some difficulty and it may be necessary to make some adjustments in both glue formula and power input for satisfactory performance.

2. Species of wood

Aside from dielectric considerations, species of wood may affect the particular glue formula used or method of machining. A glue that will operate well on maple heartwood may need more "body" to operate well on coarse-grained red oak. Strong woods, such as oak and maple, must be machined to a finer degree of smoothness than weaker woods, such as mahogany and poplar.

3. Saw versus jointer

This is a difficult comparison, but it is believed that a good sawn joint is as satisfactory as a good jointer joint for some applications and cetrainly better than a poorly made jointer joint. The torn grain that is produced by a saw may not be desirable in solid lumber furniture. For veneered core stock, however, good sawn joints may be entirely satisfactory.

Fundamentally, however, the comparison is one between a rough, weak surface which provides more anchorage for the glue, and a smooth, strong one with only the anchorage provided by the wood cavities. Reference to Figure 1 will indicate that in the first instance, improved strength at links 2 and 4 is obtained at the expense of links 1 and 5. Good adhesion to loose surface fibers cannot be as good as the same adhesion to undamaged fibers.

The main difficulties in the use of saws arise from vibration, flutter, dull teeth, saw tables out of square with saw arbor, teeth out of line, and crowding. In jointers it is vibration, dull knives, worn bearings and relation of feed speed to cutter speed. Common to both sawing and jointing is the degree to which bent and warped stock is held flat while being cut. This latter factor is extremely important because it determines how well the edges will mate when held flat in the press.

A method for observing the smoothness of a cut is the use of a straight lumber crayon from which the paper cover has been removed. When this is passed flat-wise over the joint, only the high spots will be touched and the topography of the surface will be revealed more clearly than can be determined by sighting or feeling.

4. Edge out-of-square with face

This is particularly common on narrow stock that cannot be held properly while cutting, and on thick, warped stock that is impossible to flatten during cutting. The importance of square edges has been previously stressed.

5. Edge not straight

This difficulty arises from one of two sources, either shifting of the stock during cutting, or gouging of the ends of the boards as they enter the cutters. It is a particularly serious offender, because one such miscut, even so slight as to be imperceptible, may cause failure throughout the panel. Gouging is especially insidious because the failure it causes may not appear until some stress, such as moisture change, is placed on the joint. The ends of a panel are always under more stress in service than the remainder of the panel and gouging places an early handicap on the joints at that point.

6. Quarter-sawed versus flat-cut stock

No conclusive evidence has been observed indicating any variations attributable to this factor. Occasional burning has been observed in gluing ring-porous woods, such as oak, when areas of dense summerwood appear stratified on the glue line. The difference in shrinking and swelling between quarter-sawn and flat-grained stock is perhaps of greater significance than the effect of the surface itself in the gluing operation.

7. Direction of grain, knots

The effect of the direction of grain is evidenced mostly in the cutting operation, since feeding stock against the grain will result in chipped grain which is detrimental to a good bond. Also, if the grain direction is at too great an angle with respect to the glue edge, some difficulty may be expected in preventing a starved glue line.

Knots should never appear at a joint, since they are in reality areas of very short grain. Furthermore, the dielectric properties of some knots are such as to cause arcing and burning.

8. Moisture content of stock

The effect of moisture content has been discussed with respect to power distribution in the high-frequency field. Other factors being equal, it is possible to identify the wettest board in a panel immediately as it emerges from the press. This board will be warmer to the touch than the others, which should be at room temperature. An additional effect of moisture is the stress it develops on glue joints. Wood that has been glued at a high moisture content will, in coming to equilibrium, severely stress the glue joints.

The proper preparation of stock for most woodworking operations begins at the dry kiln. This is especially true where gluing of any kind is being done. A little extra care in the drying of stock, often at no extra cost, will pay dividends all along the line in savings of reject stock.

9. Elapse of time between surfacing and gluing

It has always been considered good practice to dress the lumber immediately prior to the gluing operation. This insures a clean surface, free from dirt, grease, and dust. An additional reason should be considered in those plants where moisture control is not of the best. Changes in the moisture content *after jointing* will result in *serious distortion of the joint surfaces*. Wood that has been jointed at too high a moisture content may lose sufficient moisture from the faces within two days to cause actual crowning of the joint surface. Also, since moisture loss and shrinkage is much faster at end-grain surfaces, the width of the boards will be somewhat decreased at these points. This will have the same effect as gouging in the jointer.

The reverse is true when the stock is jointed at too low a moisture content. In this case, the ends become slightly wider and the joint surface becomes cupped, as moisture pickup and attendant swelling progresses from the faces inward. In gluing cupped surfaces, the joint will make contact only at extremities of the edge, and will look good until the planer exposes the wide glue line beneath and failure occurs.

10. Attitude of foremen

Most cutting room foremen sincerely believe they have the best prepared stock in the country. This is because they do not realize the combined importance of every little factor in contributing to consistent successful production. Ordinarily they take a certain percentage of failures as a matter of course. Corrective measures are often erroneously thought to exceed in cost the savings of material. The removal of this fallacy is the first step toward a good operation.

Some of the chief causes for three of the most easily observed defective glue-line conditions can now be listed in partial summary of the foregoing discussion.

1. *Undercure*—glue line tacky, soft to the fingernail.
   a. Insufficient time in the press
   b. Insufficient power
   c. Thin board—giving series air-gap and loss of power
   d. High moisture content in stock decreasing power in glue line
   e. High-density stock decreasing power in glue line
   f. Over-aged glue
2. *Starved Glue Line*—No glue on the joint surfaces
   a. Insufficient spread—operator should be able to view all glue lines before layup.
   b. Glue too thin—improperly mixed
   c. Exceptionally porous wood
   d. Steam pressure driving glue from the line
   e. Excessive pressure and squeeze-out
3. *Precure*—Glue cured without pressure and appearing rough and stippled, poor transfer to opposite edge
   a. Insufficient pressure
   b. Too much top pressure restricting side pressure
   c. Cauls or electrodes covered with glue squeeze-out
   d. Heating before full side-pressure developed
   e. Poorly machined stock, gouged ends
   f. Glue too old in the pot
   g. Meshing of longer, protruding boards when panels are loaded in tandem

Types of Adhesives

There are four main resin-adhesive types used for high-frequency heating. These are listed below, together with some of their advantages and disadvantages. Further elaboration will not be given, since their characteristics are well known or readily available and space is limited. Costs are based on prices prevalent late in 1947.

1. *Urea Formaldehyde*
   a. Most versatile
   b. Lowest cost, approximately 12c per mixed pound
   c. Highly sensitive to electronic curing
   d. Colorless glue line
2. *Phenol Formaldehyde*
   a. Most difficult to use
   b. Require high curing temperature
   c. Sometimes require special solvents
   d. Colored glue line (reddish brown)
   e. Arc easily
   f. Cost approximately 12½c per mixed pound
3. *Resorcinol Formaldehyde*
   a. Highly adaptable
   b. Fast curing
   c. Can be obtained non-arcing or variable in conductivity
   d. Colored glue line (red to reddish brown)
   e. Cost 45 to 50c per mixed pound
4. *Melamine Formaldehyde*
   a. Fast curing
   b. Colorless glue line
   c. Cost approximately 30c per mixed pound

The development of improved adhesive formulations is progressing at a rapid pace. Developments are in prospect for eliminating the color of resorcinol adhesives. Other disadvantages may soon disappear as demand encourages progress.

At the present time the correct choice of an adhesive may be made on the basis of cost, color and ultimate durability. The following general rules will cover most applications:

1. For extreme durability, unprotected outdoor exposure, use resorcinol or melamine.
2. For all general purposes, indoor articles, use ureas
3. Phenols are not recommended for edge-gluing with electronic heating.
4. Flour extension of resin glues is not recommended for edge-gluing with electronic heating.

The technique of handling resin adhesives will not be discussed in this paper, because no better information can be given than is found in the manufacturer's instructions and the advice of their servicemen. All users are strongly urged to follow these instructions to the letter for optimum results.

Many adhesive suppliers never consider a sale complete until the adhesive is functioning properly. Their servicemen are always ready to be on hand during the early adaptation stages and later full-scale operation to assist in any manner and assure steady performance of the adhesive. The choice of such a supplier is often as wise as the choice of adhesive type itself.

Durability

Durability is one of the most important properties of a glue line, but also the least understood. This is partly because everyone attaches a different meaning to the term. After a bond has been made, several questions must be answered. Will it hold? How long? And under what conditions? Durability may therefore be defined simply as follows:

"Durability is a purely relative term indicating that the bond will hold for the life of the product *under the intended usage*".

To the man bottling beer, durability may mean that the labels will stick on the bottles during transit and immersion in brine and yet be removed in washing for the next refill. To the man making shipping containers, durability may mean that the box will hold together under the severest handling for one trip or ten trips, as the case may be. The furniture manufacturer wants his products to remain serviceable for the normal life-expectancy of furniture under the extremes of home conditions. The home builder must consider not only long life, but also varying degrees of service requirements throughout the house.

It is clear, therefore, that durability is not a precise term, except as it applies to a particular

product used under a particular set of conditions. However, as far as the choice of adhesive is concerned, it is possible to broadly classify service conditions, on the basis of severity, and differentiate somewhat between products with respect to anticipated stress on the joints.

The broad classification of service conditions in decreasing order of severity is considered to be:

1. Unprotected outdoor exposure (*e.g.*, telephone pole crossarms)
2. Protected outdoor exposure (*e.g.*, shed rafters)
3. Severe indoor exposure (*e.g.*, bathroom or laundry fixtures)
4. Mild indoor exposure (*e.g.*, bedroom and living room furniture)

Stress on the joints is made up of two components, that created by the relative movement of the joint surfaces as the result of shrinking and swelling during moisture changes, and that of the actual load the structure was meant to carry. The latter stress can be fairly accurately anticipated. The first stress, however, is dependent upon the grain direction and the plane of cut (quarter or flat) on either side of the joint, the thickness of the joined members, the density of the wood and the magnitude and gradient of the moisture change.

A series of typical constructions will illustrate in decreasing order the varying stress produced by a given moisture change.

1. Cross-laminated flat-sawn lumber, as might be used in bases for heavy machinery or for large molds.
2. Cross-laminated quarter-sawn lumber.
3. Parallel-laminated mixtures of species, quarter- and flat-sawn lumber, as might be used for beams, arches, and lumber panels.
4. Parallel-laminated lumber, all quarter- or all flat-sawn, as used for propellers.
5. Cross-laminated veneer, as used in plywood.
6. Parallel-laminated veneer, as used in propellers.

In constructions numbers 4 and 6 it should be noted that stress is developed, not because of a total moisture change as in most of the other cases, but because of a moisture gradient from the surface inward. Complete equilibrium at any moisture content will not produce stress.

The edge-gluing of lumber places this construction at the center of the range of stress development. Most of the products in which edge-glued lumber is used today are furniture exposed to indoor atmosphere which is at the lower point in the severity range. This would indicate need for an adhesive of medium strength and relatively low durability. The choice of resin adhesive, however, does not require this type of analysis in the majority of cases, because phenols, resorcinols and melamines are in a class by themselves in durability and should always be used when the intended usage is severe outdoor exposure. Urea glues have shown their suitability for all interior products and for some protected outdoor products, except where long periods of high humidity and temperature may exist. Well-made joints with both classes will develop the full strength of wood.

Unfortunately, however, the durability of a joint is not attendant only upon the choice of adhesive. All of the factors that have been discussed in this paper affect durability in one manner or another. Choosing a resorcinol adhesive does not mean, for instance, that the ultimate in durability will be automatically obtained. The joint must also be well made, as far as technique is concerned, before confidence can be justified.

On the question of urea-resin durability, some laboratory tests indicate that urea joints may lose a portion of their strength under certain exposures. However, this has never been conclusively reflected in the usability of a product. In the ten years that ureas have been in use, and especially during the war when they were used in boats, aircraft, trucks, and many other severely exposed structures, no failures have been reported that could be traced to an originally well-made joint. Panels glued with urea glues have been observed in unusually severe exposure, such as drain boards and contact with the ground, and they have performed beyond expectation.

Although it is generally accepted that a test specimen is not always a reliable criterion of expected service, data are available showing

very little decline in strength of urea-glued plywood shear specimens exposed for one year on a New York roof. Maple blocks show no loss in strength during 2½ years exposure to laboratory atmosphere.

The use of electronics for curing resin glues must inject at least a slight question on the resulting joint durability. It has been used for such a short time that no durability records are yet available. As previously indicated, there is a possibility of decreased durability due to uncontrolled moisture losses during curing. There is also the possibility of greater durability, since the removal of moisture from the cured glue film may result in less breakdown with time. Consequent to these presumptions, therefore, durability could become an operating variable even more so than it now is.

Conclusions

The information in this paper may appear to be negative in tenor with respect to the use of electronic edge-gluing equipment, since emphasis has been placed on difficulties that may arise. This is far from the intent. The spectacular features of the operation and the many successful installations presently existing have been so well publicized that they need no further elaboration. It is the small irregularities hindering the full realization of the advantages which need further clarification, and this has been the main object of the foregoing discussion.

It will be easily apparent to those familiar with gluing problems that most of the adjustments indicated for the best performance of electronic edge-gluing equipment are in line with good gluing practice and must therefore lead to better quality of products. Many of the adjustments are also applicable to other methods of edge-gluing which may appear to tolerate poorer conditions. The term "appear to tolerate" is used because *there is no substitute for good practice* and bonds made under unfavorable conditions by any method may be expected, sooner or later, to give unsatisfactory service.

A partial list of the advantages and disadvantages of electronic edge-gluing may include the following:

1. Management must have a progressive attitude to accept some departures from former practice.
2. Many gluing malpratices become critical.
3. It is not a cure-all for the edge-gluing operation.
4. Speed, the most important advantage, is dependent upon efficient stock handling.
5. It will not tolerate poor surfaces.
6. Failures are often immediately spotted, so that stock receives no additional labor charges and may be salvaged.
7. Higher class of manpower is needed.
8. There is less labor turnover, since work is more agreeable.
9. Inaccuracies of drawing up clamps and buckling are eliminated.
10. Stock may be prepared closer to final thickness.
11. Less men and space are needed per M feet of panel.
12. Sunken joints are eliminated.
13. Almost immediate machining is possible.
14. Complete cure is not necessary in the press, when cold-setting adhesives are used.
15. Variations in heating, due to stock moisture content, density and thickness, are normal.

Discussion

Mr. Donald V. Redfern (American Marietta Company): Mr. Marra lists three basic actions in the formation of a bond, number one being penetration into the wood cavities. My experience is that this penetration is only incidental and does not materially contribute to joint strength. His second point, the wetting of the wood surface, is, in my opinion, the primary factor in the production of a good glue line. The basic concept of producing a glue line requires that this wetting or chemical attraction take place. Also, there might be one other interface considered in his list, namely, the cohesive forces between the adhesive molecules, i. e., adhesive to adhesive.

I commend Mr. Marra's paper not only for its application to high-frequency gluing, but for its all-over acceptability in the field of forming glue bonds.

Mr. John M. Yavorsky (W. T. LaRose and Associates): In contrast to the emphasis placed on the physical penetration of the glue into the wood, it has been my experience that the "wetting" action required of the liquid glue mix is the most important technological factor in the glue line.

Browne and Truax, and more recently Kitazawa, have shown that penetration of glue into wood from edge-glued surfaces occurs mainly through the open ends of pores and fibers exposed on the glued face, and that the volume of glue penetrating into the wood is a function of the slope of the grain at the glued surface.

If penetration is to occur beyond the excised cavities of the surface fibers, it must be through gouges or openings made in the fiber walls by the jointer blades. Such torn or ruptured fibers are weak and damaged and, as such, are undesirable as a base on which to anchor the glue film, as Mr. Marra has stated. If, on the other hand, sufficient glue is placed on a surface to wet the excised fiber cavities, the specific adhesion resultintg from the chemical and physical attractions of the adhesive molecules for the wood (cellulose) molecules will produce a strong glue joint.

Our practical experience in edge-gluing both hardwoods and softwoods has indicated that wood surfaces which have been properly spread with glue (wetted) will not require an appreciable assembly time, either open or closed, in order to allow penetration of the glue to occur, but rather the laid-up panel may be moved directly into the electronic press for the curing operation.

Mr. W. M. Schall (Kroehler Manufacturing Company): As Mr. Marra has pointed out, the electronic edge-bonder is not a "cure-all" for the edge-gluing operation. By actual experience, we have found that the precautions in regard to the conditioning, handling, and machining of lumber, as pointed out by Mr. Marra, must be followed very closely in order to obtain good results. I do not believe that the Utopia for the edge-bonding operation has arrived. There is still much work to be done. A research and development program should, and undoubtedly will, be carried on not only by manufacturers of high-frequency equipment, but also by manufacturers of presses and glue manufacturers so that the process can be developed to a higher degree.

A comment in regard to the durability of urea-resin: We have used the ureas in our veneer department for the manufacture of case goods since 1940 and, in a period of eight years, we have not been able to trace a joint failure back to a breakdown of the resin itself. While a breakdown may occur, it does not seem that, from a practical standpoint in the manufacture of case goods, a serious breakdown does take place, at least over a period of eight years.

A question for Mr. Marra: Since bubbling or frothing does occasionally occur in the glue squeeze-out of the glue line when high-frequency current is turned on, does it not seem possible that a certain amount of bubbling will occur in the glue line itself with a possible reduction in joint strength, even though the proper conditions of machining and handling and gluing of stock are followed? If this condition is true, what can a manufacturer who has high-frequency equipment in his plant do to protect himself against the possible breakdown in joint strength?

Mr. Marra: I would suggest that he contact the manufacturers of the high-frequency equipment and have them re-adjust the machine to obtain a slower speed of set of the glue line.

Prof. E. George Stern (Virginia Polytechnic Institute): The basic recommendations made in Mr. Marra's paper should be given serious consideration by the wood-using industries whether or not electronic equipment is used. The gluing procedures employed could, in most instances that have come to the attention of the writer, be considerably improved by the recommended practices. Fortunately, such and similar practices as mixing species with different gluing properties for the manufacture of core panels often easily can be eliminated by setting up quality-control standards. On the other hand, many core-stock manufacturers are unwilling to give consideration to even small improvements, however far-reaching they may be improving their output. When they receive a relative large number of rejections, they prefer to return to the use of old established glues, although they recognize the advantages that may accrue from the

use of synthetic resin glues under certain conditions.

Mr. Marra makes the significant statement that "lumber with widely varying moisture content should not be used in most built-up constructions." While reaching equilibrium moisture content, internal stresses in the structure, because of unequal shrinkage or swelling of material of initially different moisture content, may result in excessive warpage and cupping, or failure of the glue joints. It often is difficult to determine the actual reasons for failure when rejections are submitted for examination. Reconstruction of the actual working conditions during the time of manufacture of the rejects may, however, result in explanations with resultant possibility of eliminating the faulty practices. Thus, moisture determinations on 25 samples of 4/4 kiln-dried lumber taken during ripping and grading disclosed a range of 6.2 to 16.2 percent and an average of 9.8 percent, and subsequent determinations on 23 additional samples revealed a range of 6.0 to 13.8 percent and an average of 9.9 percent, when an average of 9 percent moisture content was aimed at. It is entirely possible that pieces with the observed extremes in moisture content were glued up adjacent to each other, since controls have not been devised to satisfactorily and efficiently separate stock having widely different moisture contents. It is evident that, during the conditioning of such glued-up lumber to moisture-content equilibrium, unequal shrinking and swelling may result in wood failure if satisfactory glue lines have been obtained or in glue-line failure if the wood is stronger than the glue joint.

It would be desirable for manufacturers to determine the acceptable range in moisture-content of pieces to be glued together. Available data on such ranges are very limited. Even if such data were readily available, the average wood-working plants would not be aware of (1) its conditions as to the prevailing averages and extreme ranges in moisture content of the lumber during processing and assembly, and (2) the service conditions for the finished products. The desire to use synthetic resin glues in their product, and the experience gained in the requirements for close control of the many manufacturing variables, have led some of the progressive manufacturers to determine acceptable ranges for moisture content of lumber during manufacture.

Many of the difficulties resulting from excessive variations in moisture content could be eliminated by passing the lumber through an automatic control unit that would select pieces with moisture content within an acceptable range, and segregate the others for further seasoning and tempering. To this end, the design of such an automatic control unit has been initiated by the writer in cooperation with the certain industries.

Edge-Gluing Engineering and Production Systems

H. C. Moser

Vice President, Gamble Brothers, Inc., Louisville, Kentucky

THE use of electrostatic energy for curing synthetic resin glues is a newcomer among the techniques of the woodworking industry. Its practicability, however, already is firmly established. Its potential advantages in efficiency of operation, reduced cost, and improved quality of product are widely appreciated and are proved in the experience of a rapidly growing list of users. The system has proved especially adaptable to edge-gluing of lumber panels, where advantages can be taken of socalled "selective heating," because it is in edge-gluing operations that curing cycles are shortest and waste of electrostatic energy the least.

Every system of high frequency edge-gluing brings together four essential elements:

1. A thermosetting synthetic resin adhesive, usually urea formaldehyde.
2. A source of electrical energy.
3. A mechanical press for holding panels under pressure during the curing cycle. An electrode arrangement to provide appropriate dispersal of power is embodied in the press.
4. A production system designed to effectively service the gluing equipment.

The resin glues presently used in high-frequency edge-gluing are substantially the same as those used commercially in cold-pressing and laminating operations for a decade or more. Many of thees old-line formulations, as well as some of the newer varieties developed specifically for high-frequency curing, are certainly capable of adequate cure in ten seconds or even less. It is quite possible that speedier or otherwise more adaptable glues may become available. For the most part, however, established adhesives can be successfully used and they are not a chief problem in the improvement of high-frequency edge-gluing.

Electronic generators likewise antedate their use in the wood-working industry. They have been used for years for dielectric heating in the plastic field. Sturdy equipment, designed for industrial use and capable of supplying ample power for any size of job, is now made by several manufacturers. This is not to suggest that generators now available are the final word, but, as in the case of resins, they already are more or less standardized and reasonably dependable for use in woodworking.

Given proved adhesives and dependable electrical units, their adaptation to edge-gluing of lumber has been largely a matter of devising suitable presses and electrodes and of working out production methods and auxiliary equipment geared to the tempo of the gluer. It is with production methods that we are here concerned.

The ultimate advantages to be obtained from high-frequency edge-gluing equipment depend in a large degree on the effectiveness and efficiency of the equipment and techniques which precede the actual gluing operation. These supporting phases influence not only the quality of the product, but also the speed of the entire operation and, therefore, the final unit cost.

A high-frequency gluer, of course, is an expensive tool and it is to be assumed that the initial installation will be accommodated to the overall requirements of the user. Once it is installed, the objective in production must be to use it to full capacity. Whatever may be the total capacity, it will be most economical to keep the gluer running continuously at maximum rate and do whatever else is necessary to bring to it the full amount of stock it can handle.

In many instances the equipment and procedures which make for efficiency in producing stock for conventional edge-gluing methods will be useful also in conjunction with high-

frequency gluers. Differences will arise chiefly from the need for increased speed and for a uniform rate of flow of material.

In mills using the common type of revolving clamp carriers, the kind, quantity, and arrangement of equipment for preparing stock, and the methods of handling it, will be designed to meet the requirements of the glue wheels. With the increased capacity of the electric gluer, it will frequently be possible to step up the output of the supporting machines to provide additional stock without adding proportionately to manpower and equipment.

Where the practice is to use random-width strips with glue joints prepared on a straight-line rip saw, for example, it is possible in many types of items greatly to increase the output of the saw by operating it in conjunction with an edge-glue jointer. Arrangement of these tools in tandem relieves the edger of half its load and actually increases its output by more than 100 percent. This arrangement permits reasonably straight rough sawmill edges to be jointed on the continuous feed jointer, without the necessity of additional passes on the rip saw. In working hardwoods in which the lumber runs narrow in width, many boards will need to pass over the rip saw only once to split them down the middle. The rough edges go directly to the jointer. If the glue jointer is set to take a cut of approximately 3/32-inch on one head, most rough sawn edges can be cleaned in a single pass. With the other head set at 3/64-inch, the edges cut on the edger will be prepared for gluing.

The tandem arrangement of glue jointer and rip saw has an additional advantage, in that it permits use of thinner saws than are required for producing sawn glue joints. With lumber at present high prices, this saving in sawn kerf can mean many dollars in a day's run.

In some plants, it is the practice to machine panels for width on a straight-line rip saw before gluing. The time required to do this obviously substracts from the total output of the saw. A separate matcher saw can be used for sizing the panels, often with greater efficiency than the chain-feed saw.

The use of a separate matching saw, moreover, makes possible a more effective grading operation and reduces the amount of repair work necessary. Successful use of a separate matcher saw, however, requires relatively large quantities of a single size and few changes in items during the course of a day's production. This requirement, it happens, coincides with the desirability of extensive runs of a single size for optimum use of most types of high-frequency gluers.

Best procedures for moving materials from cut-off saws through various machines to final gluing differ greatly between plants, depending on the character of product, number of pieces per item, type of lumber, and size of operation. The ideal condition is that in which the boards or strips need never be stacked down by hand on factory trucks at any point between the cut-off saw and the gluer. Under some circumstances, the successive machines required for preparation of the stock can be close-coupled and joined by means of conveyors, so that the strips feed piece by piece from one machine to the next. This can be done economically, only if the number of pieces per item being cut is large and the number of items being cut at one time is small. Such a system not only reduces labor cost, but permits close quantity control and good quality control, and lends itself to group incentive systems.

Where several items intended for the high-frequency gluer are produced simultaneously at the saws in order to secure greatest lumber utility, it is seldom possible to integrate the entire operation to give a smooth continuous flow of material. Under these circumstances the strips for the various sizes and grades of panels must be accumulated ahead of the gluer, in order to provide a reasonably large run without change of size.

In our plant, we have found it economical to divide the entire operation into two distinct phases, each of which is closely integrated within itself. The first phase begins at the cut-off saws and follows through edger, jointer, and grading table to accumulated storage. At this point the stock is ready for gluing. The aim is to direct to the high-frequency machine no item which will not produce at least a two-hour run.

In the second phase, the stock is transported to the gluing unit, where it goes first through

the matching saw to size the panel, then over a lay-up table to the glue spreader and directly into the gluer. This entire operation is accomplished without stacking down the sized panels at any point.

It was in this phase of the production system that we encountered the chief bottlenecks. Our gluer is a continuous-feed machine in which stock travels under the electrode at a rate of 12 to 25 lineal feet per minute. The conventional type of hand-fed matching saw, when producing panels of moderate length, is incapable of keeping the gluer filled. To meet the requirements of the high-frequency machine and still keep the advantage of a straight-line flow from matcher to gluer, a faster matcher was called for. This has been provided in a self-feed saw with a traveling arbor, which will make ten cycles, or ten panels per minute. The sawyer is enabled to match his panels ahead of the saw, with ample time to select for grade and arrangement. An automatic off-bearer delivers the panel direct from the matcher saw to the glue spreader.

Single-roll steel or carpet-covered glue spreaders of the type commonly used in hand-clamping methods are not suitable for fast operations. In this piece of equipment there still is much room and great need for improved design. Any spreader meant to spread the edge of only one strip at a time must handle stock at the rate of 240 lineal feet per minute if the gluer is producing three-foot panels at the rate of 20 lineal feet per minute. Feeding and off-bearing of such a spreader could not be accomplished by hand. A spreader handling several strips at a time must be capable of accommodating random-width stock, with close control of spread on straight and twisted strips alike. Better spreaders are needed. Inadequate spreaders can be the source of much difficulty in the production system for high-frequency gluing.

A question frequently raised concerning the operation of high-frequency presses concerns the possibility of surfacing panels immediately after leaving the gluer. This, of course, depends somewhat on the degree of cure of the resin effected in the press. With advanced cures, surfacing can be done at once. Our tests have shown no evidence that sunken joints will develop, or that any distortion will result from stored heat.

There are other considerations than strength of the panel and danger of sunken joints which have a bearing on the matter. Unless the surfacer operates at the same speed as the gluer, lost time will be involved at the planer. The character of panel being produced, its size, and the condition of the planer knives also help to determine the proper system. In our case, we find it most practical to accumulate glued items until complete or until a considerable quantity has been run before surfacing. When a variety of items is being glued, as would normally be the case in hardwood dimension or furniture plants, separation of the gluer from the planers is likely to afford closer control and more efficient production.

It is apparent that no one production system can be devised to fit the requirements of all plants, or even of any two plants. The required total output, the floor space the available auxiliary equipment, the type of product, kind of lumber, and whole complex of factors must be weighed. Careful analysis of all phases of the operation is necessary. In general, high-frequency provides an opportunity for stepping up production rates with reduced manpower all along the line. The manufacturer who would do his edge-gluing with high-frequency will do well to analyze carefully the operations which support the gluer. It is easily possible that any apparent deficiencies in the gluer may actually lie instead in the production system behind the machine.

FOREST PRODUCTS RESEARCH SOCIETY

Application of Radio-Frequency Tooling

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Because of the specialized nature of radio-frequency tooling, the electronic technician should understand that the woodworking shop ought to be his laboratory, and gear his experiments to the practices and knowledge of the user, and to the materials and conditions that are standard in the field. Before installing radio-frequency equipment, a thorough time study of the individual problem is necessary to justify expenditure of money and time. A satisfactory end product is produced with high-frequency applications when quality control is strictly adhered to.

This paper describes methods of designing and making tools for the fabrication of such articles as hollow-core flush doors, bent plywood furniture, venetian blinds, and drawer-front paneling, and for edge-banding operations. Methods suggested in this paper lend themselves satisfactorily to all other types of wood fabrication.

Introduction

THE most successful application of radio frequency to wood fabrication has been carried out by millwrights, cabinet makers and woodworking machine operators. For the past seven years these men have witnessed engineers and technicians design and build radio-frequency tooling. This paper deals with applied knowledge of general shop practice, wherein an understanding of a complete process for the manufacture of a given product is more essential than all the technical curves and formulas. Knowledge of this nature cannot be gained in the laboratory. Close coordination with the production men in wood fabrication plants will ascertain the value of the radio-frequency tooling and point out the changes necessary to meet their standards. The knowledge of tool-design requirements and manufacturing techniques among the wood-products manufacturers and personnel is of a greater scope than than possessed by all the combined woodworking-machine manufacturers and electronic technicians. Therefore, it is imperative to acquire the assistance of the proposed user before fabricating a radio-frequency generator and press for a woodworking operator. Applied knowledge of shop practice consists of quality control of standard procedure. Proper kiln drying, stress-free lumber, humidity and temperature control and glue room technique are a few of the essential procedures. Control of glue application to wood of correct moisture content is equally as important as presses and tools to apply adequate pressure. Electrodes should be correctly coupled to the radio-frequency generator and a correct frequency and power output with proper voltage applied to glue of known and tested characteristics.

The principles involved in applying radio-frequency energy to a specific tool require a time study to justify the expenditure of time and money. The most important step before installation is a time study of the fabricating operation contemplated. In many instances, a radio-frequency tooling installation adds cost to the article produced. A tooling engineer should start his survey with the dry kilns to see that a schedule in a properly designed kiln is followed to assure the fabricator that no case-hardened, honeycombed or warped lumber will go into the assembly. Maximum dimensional changes during and after manufacture can be controlled. The re-sawing, milling of lumber and preparation of dimension stock can then be assured at a lower cost. When the temperature in the lumber storage and fabricating rooms drops below 70 degrees Fahrenheit, gluing of wood with synthetic resins should not continue. Therefore, a conditioning room with proper temperature and humidity should be used before fabrication.

Satisfactory methods of designing and making tools for wood fabrication will be dealt with on each individual subject.

Hollow-Core Flush Doors

Hollow-core flush doors consist of many designs and necessitate different construction of assembly jigs for the core fabrication. The non-

Fig. 1.—Door core coming out of assembly magazine.

glued assembled core of a flush door of one type is shown in Figure 1. Stiles are mortised in a sticker. Lock rails, intermediate and top rails are machined to a tight fit with a double-end tenoner. Conveyor belts move the stock from a conditioning room to an automatic hopper and magazine press. Stiles, rails and lock blocks are pressed together by a hydraulic cylinder, when a timer switch actuates a solenoid controlling the hydraulic valve.

With release of the hydraulic press, the divided table bed lowers the door frame onto a powered belt conveyor. The conveyor belt is on a plane level with the center opening of the double-roll glue spreader, into which the door core is propelled and thence onto a quarter-inch plywood panel. A powered roller conveyor is used to carry the sandwich construction to an automatic squaring and spotting press in the conveyor line (Figure 2).

Six individual one-kilowatt generators are used to spot cure ten square inches of glue line area on corners and center, while air cylinders apply pressure in three directions to square the door. A time delay releases the air cylinder, allowing the squared door to drop onto continuous powered rollers. The final high-frequency curing press (Figure 3) is operated by air pressure with multiple fire hoses. A storage tank of 60 cu. ft. capacity, at 100 lb. pressure, is connected to the input by solenoid-actuated control valves which allow the press to close in one second. Similar valves connected to the exhaust release in the same time.

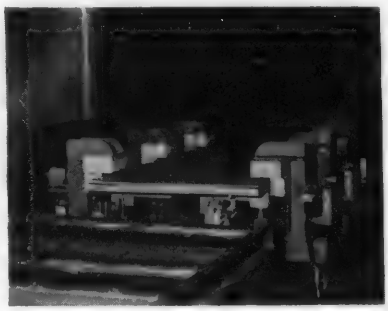

Fig. 2.—Flush-door squaring press.

Electrodes

Electrodes are fabricated as in Figure 4. They are constructed of fiberglas and silicone resin under pressure, with a silver-plated copper electrode imbedded in the resin but allowed

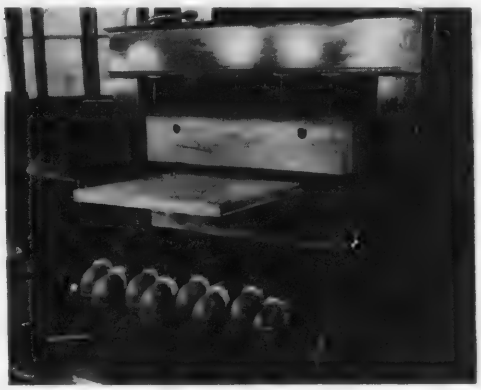

Fig. 3.—Final flush-door press.

to project above the silicone and glass 0.010 inch to eliminate all air gaps between the electrode and face veneer. A slight air gap is allowed between silicone electrode base and adjacent electrode to prevent radio-frequency losses into the caul board. Silicone glass and electrodes are mounted on neoprene bases to allow take-up in uneven surfaces. The flow of door assemblies into the third press is controlled by a micro-switch contact located 12 inches in from the outlet end of the press. Ten doors are necessary in the press line to start the full automatic cycle, which repeats itself by time delay and electronic timers every 30 seconds. It is necessary to use knurled conveyor rollers to convey each door, butted against the

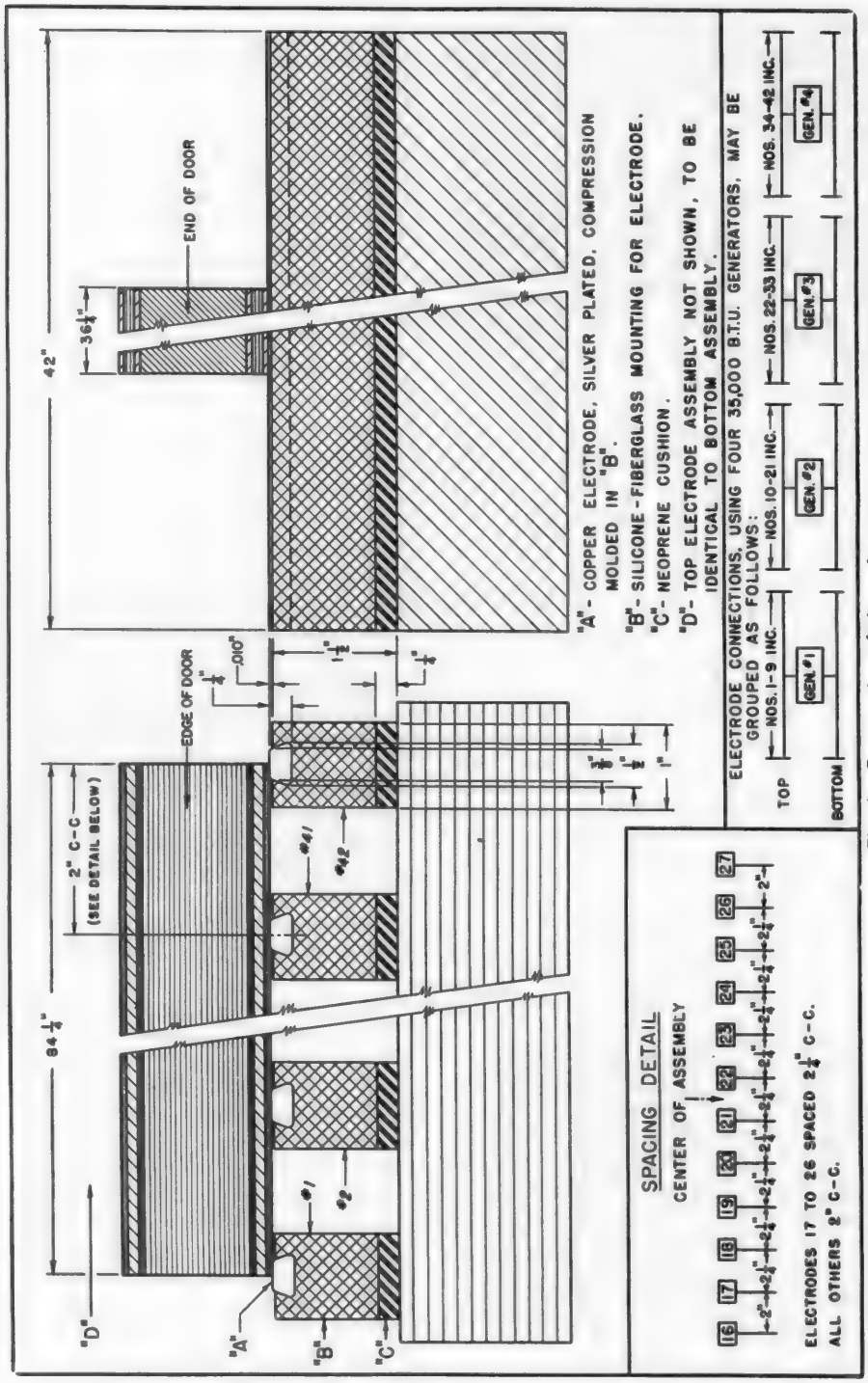
42"
36½"
END OF DOOR
84¼"
2" C-C
(SEE DETAIL BELOW)
EDGE OF DOOR
.010"
"A"- COPPER ELECTRODE, SILVER PLATED, COMPRESSION MOLDED IN "B".
"B"- SILICONE-FIBERGLASS MOUNTING FOR ELECTRODE.
"C"- NEOPRENE CUSHION.
"D"- TOP ELECTRODE ASSEMBLY NOT SHOWN, TO BE IDENTICAL TO BOTTOM ASSEMBLY.
ELECTRODE CONNECTIONS, USING FOUR 35,000 B.T.U. GENERATORS, MAY BE GROUPED AS FOLLOWS:
TOP
NOS. 1-9 INC.
NOS. 10-21 INC.
NOS. 22-33 INC.
NOS. 34-42 INC.
GEN. #1
GEN. #2
GEN. #3
GEN. #4
BOTTOM
SPACING DETAIL
CENTER OF ASSEMBLY
16 17 18 19 20 21 22 23 24 25 26 27
2" 2½" 2½" 2½" 2½" 2½" 2½" 2½" 2½" 2½" 2½" 2"
ELECTRODES 17 TO 26 SPACED 2½" C-C.
ALL OTHERS 2" C-C.

Fig. 4.—Construction of electrodes.

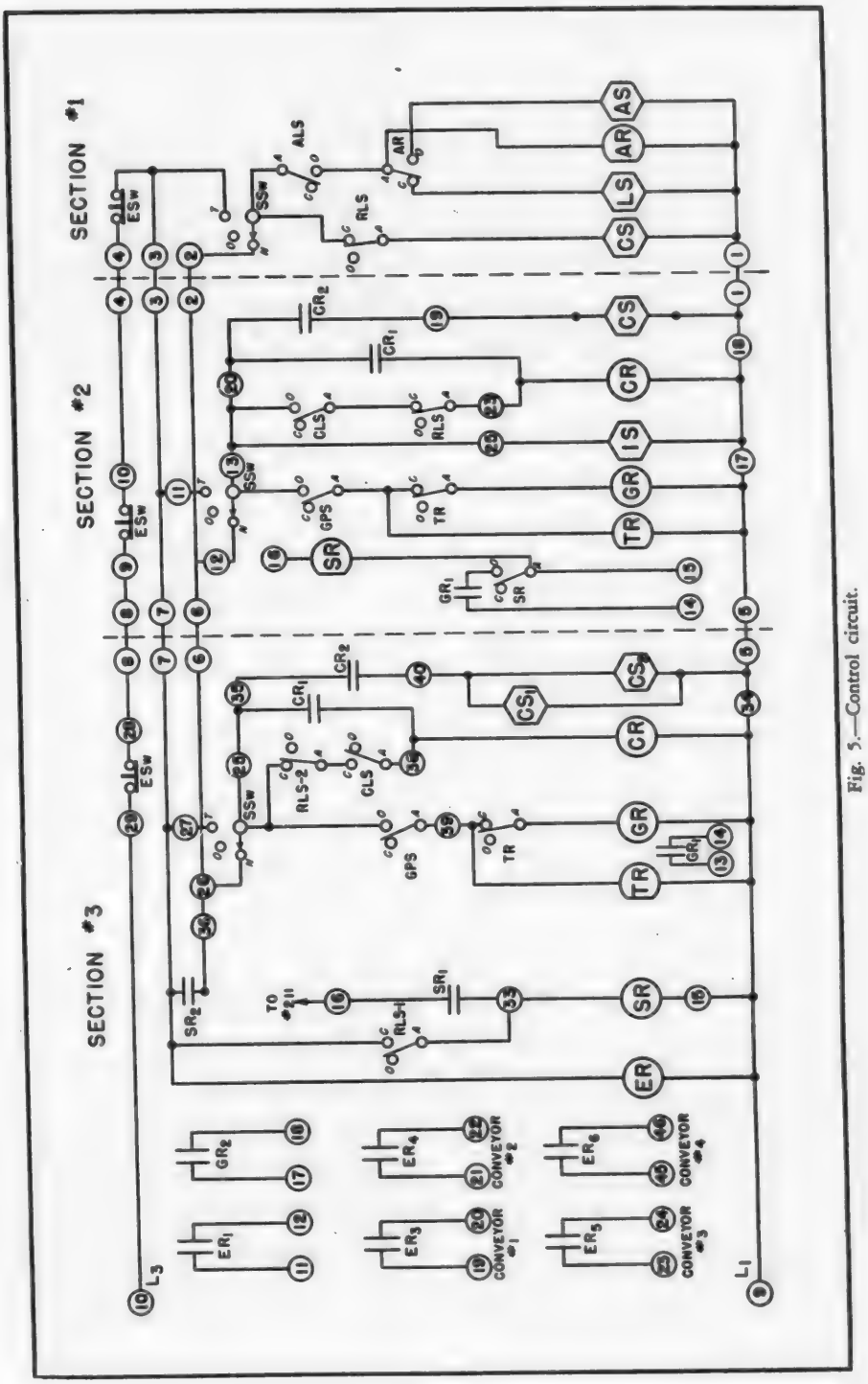

Fig. 5.—Control circuit.

next door, onto the final curing radio-frequency press. As the sandwich assembly starts in motion, it is necessary to drive the interposing conveyor line to higher speeds. The conveyor moving the assembly into the squaring press travels at 50 feet per minute. The speed out of the squaring press is 60 feet per minute. Spring-loaded ceramic rollers inserted between electrodes allow the doors to travel onto the radio-frequency press at 60 feet per minute, propelled by adjacent doors. The door is stopped in exact position by the one-second closing of the press. A micro-switch control located within the press, one foot from the outgoing end, stops the door in the selected position when the door is travelling at one foot per second. An outgoing power conveyor, moving the door to a high-speed profiler, necessitates travel at 150 feet per minute to move the completely cured door out of the radio-frequency press before subsequent closing on the following door.

All movements and control switches are tied in and synchronized to four 34,000–B.T.U. radio-frequency generators. The electrodes in a horizontal line are alternately connected to the generator leads. Curing of a smaller area of glue line with each generator allows a higher frequency to be used and a greater amount of power can be applied to the ends of each door. Where glue squeeze-out occurs, it is cured only by conduction from the adjacent heat of the glue line.

Figure 5 is a control circuit for this assembly operation. The magazine hopper press (Figure 1), with modification of design, will assemble various type core assemblies, including the paper ring, lattice design, and honeycomb paper core.

Bent-Plywood Furniture

Through the development of high-frequency equipment, bent-plywood furniture now is being produced in mass-production quantities. Single and compound curvatures have become standard production items, high-frequency equipment enjoying the added advantage of forming the plywood and molding the curvature in one quick operation. Thus, in furniture making, we have become accustomed to seeing the arm and leg of a chair formed together in one continuous piece of plywood, the back and seat curved from another.

Fig. 6.—Inserting veneer into die.

The plywood is conditioned and cut to rough dimensions. The finished plywood can consist of either hardwood veneers throughout, or the core can be formed of lower-cost veneers and faced with mahogany, maple or other decorative hardwood veneers.

Before placing in the press, every other piece of veneer is run through a double-face glue spreader. Then the veneers are arranged properly and inserted into the die (Figure 6). A punch made of laminated hardwood is raised and lowered with an air cylinder (Figure 7). The press is constructed of channel steel of sufficient strength to stand the pressure required. The cross member on the press, which the air cylinder activates and to which the die is attached, is locked into position at the bot-

Fig. 7.—Bringing down punch.

tom of the stroke by dogs which are welded into the main press frame.

The fluid pressure then is introduced between the punch and die face, using ordinary fire hoses, which travel up and down with the punch, for pressure. The hoses are connected to a conventional air-pressure line.

The die is made of hollow Kirksite and is filled with a heat-transferring oil. This oil is brought to a minimum of 150 degrees Fahrenheit by using a resistance heater suspended inside the die. This conditions the die so it will not absorb any of the high-frequency energy during the curing cycle when the die is cold. It maintains its own heat after an hour or so of operation.

The die acts as one electrode; the other electrode is made of segmented copper cemented to a special neoprene band to allow for expansion and contraction, and also to keep the pressure on the back of the veneers in a uniformly fluid condition. This electrode is completely insulated from the rest of the press frame and die.

Of a universal type, the press can be fitted with different shaped dies which are easily interchanged.

On an operation such as described above, a 10-kilowatt high-frequency generator is used. The curing cycle is very rapid, the actual time depending on the thickness of the finished bend. The controls of the press can be made completely automatic if production warrants such a move.

Edge Banding

Edge banding has been speeded up in the woodworking industry by the introduction of high-frequency machinery. The first step in edge banding the modern desk (Figure 8) is to place the table top in the jig, which centers it by locators holding it in position and away from the electrodes. The glue is spread on the veneer banding, which is then slid into position between the electrodes and the desk edge preparatory to curing. The banding is properly located by stops mounted on the jig. The electrodes are imbedded in a silicone glass fiber laminate. The face of the laminate acts as the pressure shoe on the banding. The pressure is introduced with a single 1¾-inch fire hose at-

Fig. 8.—Edge banding jig.

tached to a conventional air-pressure line, the hose being located back of the glass shoe and following completely around the periphery of the desk. The jig is so constructed that it brings the pressure first to the peak or top of the desk edge and gradually follows around to the heel or bottom (Figure 8) in a wrapping motion, avoiding all possibilities of wrinkling or looping the veneer.

The operation can be accomplished with a small portable woodwelding generator. The jig is made with a foot-kick lever for unloading after the cure has been completed.

Venetian Blinds

In setting up jigs for the manufacture of venetian blinds by high-frequency methods, two welding heads, in which electrodes have been embedded, are mounted on a specially constructed bench or horse (Figure 9). The

Fig. 9.—Assembly jig for venetian blind valance.

Fig. 10.—Book-end type jig.

top is made of two parallel 2 by 8-inch boards running the full length of the bench. The boards are spaced so as to form a slot down the center, allowing the two heads to slide up and down the entire length and to be locked at any point to accommodate any length of venetian blind cap desired. The heads are made to receive all three parts forming a venetian blind—the facia board, the return and the cap. The return and facia are usually assembled with a 45-degree joint. All three members are then held in place on both ends of the assembly unit under toggle clamp pressure during the curing cycle. A one-half kilowatt woodwelding generator has sufficient power to cure the glass lines in such an operation.

It has been found that the ultimate strength of these electronically welded assemblies is many times greater than those manufactured by older methods.

Drawer-Front Paneling

In order to use up small pieces of panel which accumulate, many furniture plants use the pieces to make drawer fronts. The exposed edges of the laminations are covered with 1/28-inch veneers, the glue joint being cured electronically. This is done with a simple electronic jig (Figure 10). The panel is held vertically between the book-end type locators. The glue is spread either on the surface of the banding veneer or on the laminated edges of the panel, according to convenience.

The toggle clamps are mounted on a thin layer of hydropress rubber for flexibility. The stray-field electrodes are mounted on a wooden bar connected to the clamps and are separated by a piece of mycalex insulating material, which acts as the pressure shoe when the clamps are actuated to hold the veneer band tightly.

The curing is accomplished by the use of a small portable generator, assisted by a tuning unit constructed of a variable condenser and tap switch. This equipment allows a rapid change to large or small areas.

Flush Doors

Making flush doors in the conventional method entails considerable labor. After the milling, the material is layed up to the proper width and cut off to length (Figure 11). It is then put through the core stock press and

Fig. 11.—Cutting off core stock.

Fig. 12.—Glue press.

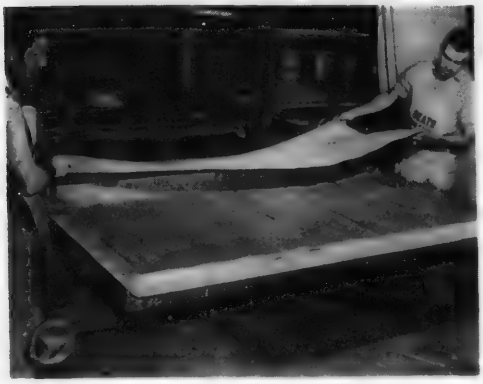

Fig. 13.—Placing veneer on core.

bonded. From there it goes to the planer for cleaning up both sides. Then the core is moved to the glue spreader (Figure 12) where the cross banding and face veneers are applied (Figure 13), then to the veneer press for final curing (Figure 14).

A newer and much faster method of manufacturing flush doors has been devised, wherein material which has previously been surfaced on both sides is put through a straight-line rip saw and then directly through a vertical glue spreader. This new flush-door welder is so constructed as to allow a continuous flow of core stock through the machine. The stock is cut to length as it leaves the welder. It is stacked near the machine until the entire batch is finished and then goes through the same machine for applying cross band and face veneers to the core (Figure 15).

Fig. 14.—Veneer press.

Silicone-glass pressure members are inserted in the air-gap spacing (Figure 4) to assure adequate pressure during the heating cycle, when cross band and face veneer are bonded to the core.

Since the glue line presents a lower resistance to the RF field, the major portion of the current follows the glue line in cross band and face veneer. This action is also accelerated by the placement and connection of the electrodes in such a way that the RF field through the core stock is a small percentage of that which flows through the glue line.

The electrode assembly is driven from a balanced circuit so that there is no actual ground used on any electrode.

The electrodes along the horizontal line are alternately positive or negative to each other, but at any instant the alternate electrodes are the same RF voltage above ground. This minimizes the unwanted stray radiation and further aids in confining the field to the glue line.

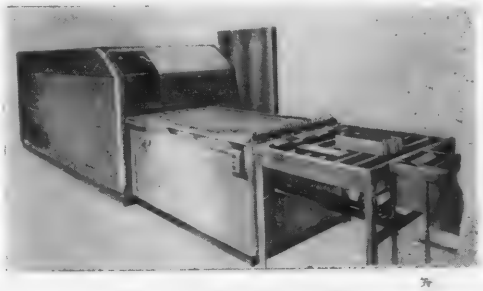

Fig. 15.—Flush-door welder.

Prefabricated Houses

After milled components have been cut to their proper lengths, they are brought to the subassembly section. Multiple jigs are installed in sufficient numbers to meet the production requirements. The high-frequency electrodes are built in as an integral part of the pressure system. After these subassemblies are bonded they are placed on the overhead conveyor line, which moves them to the major assembly jigs. Here the high frequency is automatically applied to the area to be cured in the same manner as the smaller jigs.

The final presses are automatically controlled and synchronized with the rest of the line. Their only function is to electronically bond

the panel to the fully assembled frame sections.

After the stressed skin panel is bonded to the core, it is run through a high-speed profiler to obtain the exact dimensions which are required for fast final assembly of the house. Following this operation, the complete panel sections should be properly sealed to prevent moisture take-up, assuring the tolerance necessary to make possible the installation of the keys which lock the adjacent sections in place.

The vapor barrier within the stressed-skin panel should be taken into consideration if radio frequency is going to be used, since various types of insulating materials absorb a great amount of RF power.

The success of these steps are closely dependent on the ability to enforce within the plant strict quality, temperature and moisture control, as well as proper inspection of incoming material.

Fig. 16.—Pre-fabricated house sub-assembly jig line.

Synthetic resin glues should be chosen very carefully for the job. A room-temperature or intermediate-temperature thermo-setting glue will be found best for fast cure at lower power requirements. Curing time for some assemblies will be reduced by using a partial cure to create sufficient bond strength to permit handling, and then allowing the balance of the cure to take place at room temperature. Assemblies of this nature should be stored in a heat controlled and humidified room until equilibrium of moisture content is attained.

Resorcin, phenol, melamine and melamine-urea will produce a long-life, boilproof bond. The catalyst used in each type resin should

Fig. 17.—Sub-assembly jig (prefabricated houses).

have a high or low conductivity based upon speed of cure required. An electrolyte in the resin is advantageus to fast curing, but many disadvantages occur to offset the good features. Arcing when electrodes are in contact with the glue line, and high heat in ureas causing low strength bonds (Reference: Tests performed by Bror L. Grondal, Professor of Forestry, University of Washington) are only a few of the difficulties encountered.

When urea is fortified with melamine, a strong electrolyte can be used without harm to the glue for a rapid cure. Acid-type phenol resins have proven satisfactory for long pot life and fast cure.

Resorcinal glues usually flow easily when heated, thus causing considerable squeeze-out which will arc upon contact with the electrode. Resorcinal and ureas with high solids have the

Fig. 18.—Final wall panel press for R. F. bonding.

advantage of creating strong bonds with low pressure and thick glue lines, provided high temperatures are not applied.

Wetting agents can be used to advantage where a B-stage resin is allowed to precure and a low conductivity is encountered in the volatile free resin.

Numerous methods of electrode design, spacing, applied voltage, frequency selection, insulated electrodes and tuning stubs will be applied by each generator manufacturer and engineer; but all lead to the same result, with a satisfactory low-cost wood product obtained.

Conclusions

The technical knowledge gained from actual research and practical experience within the Forest Products Research Society group, dovetailed with allied fields in wood utilization and fabrication industries, will bring forth a demand from the entire world for superior, lower-cost, long-life wood fabricated products and new methods for making them.

Based upon the demand, dielectric tooling and radio-frequency generators will be low in cost, tremendous in demand, and simple to operate.

Discussion

Mr. R. L. Hiller (American Cyanamid Company): Mr. Cunningham's comments on the use of melamine-fortified urea adhesives on high-frequency curing operations rather than straight ureas, thereby making it possible to cure at higher temperatures, is a very interesting theory which, to the best of my knowledge, has not been proven.

The development of resin adhesives for specific application on equipment using high frequency as a means of cure has, for various reasons, been very slow. I believe one of the principal reasons is the fact that, until recently, there has been no standard pressure device devised with standard high-frequency equipment which was manufactured for a specific application to perform a standard operation common to many plants. Up until about six months ago, when a resin manufacturer was called in on a new high-frequency installation to make adhesive recommendations, he found that the particular press equipment was specifically designed to do a certain job peculiar to the plant in question. In addition, he usually found that there was more or less disagreement between the press manufacturer and the high-frequency supplier as to whether the other's equipment was suitable for the operation. Under such conditions, if, after considerable experimentation on the equipment, an adhesive formulation was developed to meet the particular requirements of that operation, such a formulation would not necessarily prove satisfactory on the next installation; in fact, in most cases, it did not.

With the advent of edge-gluing high-frequency presses of standard design, I believe it will now be possible for resin manufacturers to carry on field development programs which will produce adhesives giving satisfactory results on high-frequency equipment. Urea-melamine combinations may eventually give certain advantages, such as Mr. Cunningham mentioned, but the meager test data to date give no such indications. In transverse heating of assemblies with high frequency, using melamine-urea adhesives, it has generally taken a longer cure cycle than with straight ureas. I know of no case where it has been possible to increase the curing temperature and reduce the cure time.

Parallel curing of assemblies with high frequency, using melamine-urea combinations, has been even more discouraging and, for the most part, there is a complete lack of adhesive bond. As it appears at the present that edge gluing will be the field in which high-frequency equipment is to be used most extensively in the near future, this problem becomes one which will very likely receive considerable attention by melamine resin manufacturers.

Regarding availability of melamine and melamine-urea resins, both are available in quantity to meet current demands. Straight melamine-formaldehyde resins for wood gluing are currently (March 1948) about $0.38 per pound in dry powder form. Melamine-urea formaldehyde resin adhesives are currently selling at $0.24 per pound in dry powder form containing small additions of ligneous filler. All prices given refer to carload quantities.

Mr. James F. Hamilton (Perkins Glue Company): Mr. Cunningham comments that the

glue companies have let the industry down. I should like to remark that, at the January 1947 High-Frequency Gluing Conference held at the University of Washington in Seattle, I outlined three types of resin adhesives that our company found well qualified and offered for high- and a melamine-urea type. Mr. Cunningham now finds the use of melamine-urea excellent for such work and advocates its use. In other words, gentlemen, speaking for one glue supplier, we do not feel that we have "let the industry down". After all, we have recommended three distinct resin types for some time now, for various applications, but it is the prerogative of the purchaser to make his own selection.

Mr. Glen P. Harris (Monsanto Chemical Company): I should like to point out that it is the easiest thing for an individual to blame the glue for a poor glue bond, despite the fact that there are a number of factors other than glue which can be responsible. Resin adhesives were in use long before the introduction of high-frequency equipment into the woodworking field. I do not believe that the manufacturer of such equipment can sell this new "tool" and expect to step back and say: "It's up to the glue manufacturers."

I will agree that the development of new glues should proceed to facilitate or improve their operation in the H. F. field and there have been comments from the floor that this is being done. However, work should also be done by the H. F. equipment manufacturers to improve the operation of these units.

Mr. W. G. Raoul (Cavalier Corporation): More experience is needed on possible damage to glue joints from over-heating. Radio-frequency cures can be extremely fast (we have often glued up poplar cores in six seconds). Mr. Cunningham suggested the dangers of delayed failures in such joints, which might appear after the product is in use. He had no convincing data, however. The subject will be increasingly important, particularly for fast assembly operations involving a limited area of glue line.

PAPERS PRESENTED BY TITLE ONLY

Carbonization of Douglas-Fir Sawdust

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THE problem of profitably disposing of wood residues from sawmill operations in the Pacific Northwest dates from the start of large-scale lumbering in the region. The principal use of such material is, of course, as fuel, with pulp, pressed board, and specialty products using a smaller part. Despite these outlets, there still exists a large quantity of potentially valuable raw material for any process that can convert it into a profitable product.

According to a survey conducted by the Bureau of Census, 4,895,210,000 board feet of lumber were cut, in the Douglas-fir region of Oregon alone in 1946[3]. Approximately one unit (200 cubic feet) of wood residue is produced per thousand board feet of lumber, making about 4,895,210 units of potentially usable Douglas-fir wood available during 1946. The portion of this wood that is currently unused is not known exactly, but a survey made in 1944 indicated that 18.5 percent of the sawmill residue produced in Oregon and Washington was not used[5]; on this basis, some 900,000 units probably were unused in Oregon during 1946. The amount of sawmill residue may be greater at the present time, because of increased lumber production inasmuch as the West Coast Lumbermen's Association recently estimated the 1947 production of lumber in the Douglas-fir area of Oregon and Washington at 8,000,000,000 board feet, a gain of about 200,000,000 feet over 1946[1].

Several attempts have been made in recent years to develop a charcoal industry in the Northwest to utilize sawmill residue, but none survived for very long for various reasons, probably the most important being that of low profits. Recently, favorable markets plus intensified efforts in more complete utilization have increased interest in the possibilities for producing softwood charcoal from sawdust or hogged material.

The Oregon Forest Products Laboratory, in 1943, inaugurated a research program to determine the feasibility of producing charcoal from sawdust. Progress has been made despite manpower shortages during the war years. The equipment now in use should probably be classed as "large laboratory size", since it is neither sufficiently large nor complete enough to be called a pilot plant. The unit consists of a rotary retort, by-product recovery equipment, and milling and pressing machinery. The nearly horizontal retort is 17 inches in diameter, 20 feet long, and drops 7/16 inch per foot of length. Sawdust is fed from a hopper into the high end by a screw conveyor. The retort is heated by a tube 6 inches in diameter, extending lengthwise through the center of the shell. A gas burner fires into the low end of the tube, and stack gases are discharged through outlets at the high end of the retort in such a manner that they do not come in contact with the wood gas produced in the carbonization process. The temperature is highest at the discharge (low) end of the retort and becomes progressively lower toward the feed (high) end. Wood gas from the carbonizing sawdust is exhausted from the feed end of the retort and is passed through a small primary cooler, where it is washed and some of the tars condensed by a water spray. The washed gas then passes into a scrubbing tower, 14 inches in diameter and 10 feet high, where it is further cooled and where virtually all of the tars are removed. This tower contains baffles that provide large cooling surfaces as the gas passes upward countercurrent to the wash liquor. Settled tars are collected from a 50-cubic foot vat, where the wash liquor is accumulated and recirculated. No attempt is made to recover the distillation byproducts other than the settled tar. The water-soluble products are allowed to collect and to recirculate as wash liquor. After washing, the gas is conducted to

the discharge end of the retort, to be used as fuel for the sawdust-charring process. The retort first is brought up to the required temperature by utility gas; after the charring reaction starts, sufficient wood gas is generated to more than supply the fuel required to maintain operation.

The charcoal is discharged through a double valve arrangement at the low end of the retort and is stored in air-tight metal containers for several days, until it can safely be put into burlap bags. For briquetting, the loose char is pulverized in a pan mill and mixed with a binder, either recovered wood tar or petroleum tar, and briquetted in a Belgian press. Green briquets are then either dried or calcined, depending on their proposed use.

The following data give a general idea of the operating conditions of the retort. The data do not represent any particular experimental run, but are a composite of numerous trials and are intended only to show the typical performance of the retort.

Speed of rotation	3 rpm
Temperature, discharge end	1250° F.
Temperature, feed end	350° F.
Feed	100 pounds dry wood material per hour
Retention time	25 minutes

Under the foregoing conditions, if the sawdust has a moisture content of less than 15 percent, wet basis, a char with less than 10 percent volatile combustible matter can be produced consistently. The retort was originally designed to char sawdust with a higher moisture content, but it has not proved to be satisfactory for this purpose.

Following is an average yield of products obtained from the destructive distillation of Douglas-fir sawdust:

	Percent by weight
Pyroligneous acid, soluble tars, etc.	38
Gas	35
Charcoal	23
Settled tar	4
	100

As mentioned previously, the pyroligneous acid fraction is not recovered, but is allowed to circulate in the wash liquor. Allowing the water-soluble products to remain in the wash liquor results in more effective scrubbing of the gas, and it also reduces tar build-up in the pipe lines. The yields of methanol and acetic acid have not been investigated thoroughly, since they are too low to be of commercial importance.

A typical charcoal has the following proximate analysis:

	Percent by weight
Fixed carbon	88.6
Volatile combustible matter	9.5
Ash	1.9
	100.0

The charring of one pound of dry wood produces about 6.5 cubic feet of gas, having a calculated heating value of about 420 Btu per cubic foot and the following analysis:

	Percent by volume
Carbon monoxide	33.6
Nitrogen	19.8
Methane	16.7
Carbon dioxide	10.9
Ethane	6.3
Hydrogen	5.8
Oxygen	3.6
Illuminants	3.3
	100.0

The presence of the comparatively large amount of nitrogen is probably because of air leaks in the apparatus. If this is true, the volume of gas measured during the charring of a given weight of wood is greater than that actually produced, and the yield of charcoal is decreased by oxidation of the hot carbon.

The nature of the settled tar has not been investigated completely. The only practical use thus far found for it has been as binder for briquetting char, for which it serves very well. In appearance, the tar is a viscous black fluid, having a specific gravity of about 1.15. Some preliminary work has been done on the physical characteristics of the tar. Table 1 shows the result of fractionating a sample of tar that had been refined to remove solid impurities.[2]

TABLE 1.—TEMPERATURE RANGE, PERCENTAGE, AND CHARACTER OF TAR FRACTIONS

Fraction	Temperature range, Degrees C	Percentage distilled, Percent by weight	Character of fraction
1	To 210	0.1	Pale amber liquid
II	210–235	1.6	Pale amber liquid
3	235–270	8.6	Pale amber liquid
4	270–315	17.0	Golden brown liquid, solid separated out
5	315–355	22.6	Dark brown liquid, solid separated out
Residue		47.1	Black solid
Loss		3.0	

More research should be done on the tars to determine their possible commercial uses and basic chemical constituents.

At the present time, the Oregon Forest Products Laboratory plant is being operated for the purpose of producing rather large quantities of char, to be used as test lots by private firms interested in the possible utilization of charcoal in chemical and metallurgical processes. Experimental work has proceeded virtually as far as is practicable with the present equipment. The plant is neither large enough nor complete enough to supply the production and cost data necessary to determine the economics of a commercial-scale plant. Since it is the purpose of the laboratory, either to prove the process economically unsound or to develop it to a point where private interests will take over, it has been deemed necessary to construct a pilot plant. The design work and cost estimates are nearly complete for the new plant, and it is expected that construction work will begin within the year.

This plant will have a capacity of one ton of charcoal every 24 hours, and will consist of a rotary dryer, a rotary retort, storage facilities for loose char, milling and pressing machinery, and a briquet calcining oven. The dryer will be of a steam-tube type, 3 feet in diameter and 20 feet long. The rotary retort will be 2 feet in diameter and 24 feet long, externally gas fired, with an integral char cooler at the discharge end. Loose char from the retort will be further cooled and conditioned in a pneumatic conveyor that will elevate it to storage bins. From storage, char will drop into a 6-cubic foot pan mill where it will be pulverized and mixed with a suitable binder. The mix will then be briquetted, either with a Belgian press or an extrusion press. The use of an extrusion press for briquetting char is as yet untried; however, experimental work on this is scheduled to begin soon. After pressing, the briquets will either be dried or calcined. For use where volatile matter does not interfere, satisfactory briquets can be prepared by a simple drying process. This operation has been performed in a small lumber kiln. Since this laboratory has kiln facilities, this method probably will be used. For metallurgical use, where volatile matter is undesirable, trays of briquets will be calcined at high temperature in a horizontal, externally-fired, tube oven. Following this final processing, the briquets will then be cooled, sacked, and stored.

All of the experimental work to date has been on Douglas-fir sawdust, and the major part of future work will be confined to this material. It is expected that, as future conditions permit, the charring of other species will be investigated.

The future for softwood charcoal is not discouraging, despite failures in the past. According to present information, a fairly good market exists today, and it undoubtedly could be expanded if sufficient charcoal were available at moderate prices. Samples have been distributed for domestic use by this laboratory, and reports from users have indicated that charcoal briquets are very satisfactory for home consumption in this area. A sample of calcined briquets was used satisfactorily in a trial electric-furnace reduction of nickel-iron ore at the U. S. Bureau of Mines Station, Albany, Oregon[4]. Much char may be used by electrometallurgy plants established near hydroelectric power sources in the Columbia Basin. Tests are now in progress to determine the suitability of charcoal for electric furnace use. Thus far, it has proved to be acceptable, and early fullscale trials are contemplated. Some interest has been shown in the possibilities of using char briquets for foundry work. The manufacture of carbon disulfide may take some charcoal, although heretofore softwood char has been considered to be rather unsuited to this use. There are numerous other outlets for charcoal, and more probably will be developed.

Production of the quantity of charcoal required for making commercial tests has been one of the major problems encountered in the development of a softwood charcoal process by the laboratory and by other investigators. It is not uncommon to use several tons of char in a single trial, and it is difficult and expensive to prepare large amounts of charcoal with experimental equipment. The fact that the construction of a moderately large plant cannot be justified without extensive preliminary tests makes a "vicious circle". It is the intention of the laboratory to strike a balance between capacity and cost factors. The proposed new

pilot plant will have the capacity to produce charcoal for industrial trials, but it will retain the control and flexibility of operation necessary in an experimental unit.

While it is still impossible to draw any conclusions as to the feasibility of producing softwood charcoal on a commercial scale, the prospects are definitely encouraging. By modifying the carbonizing process to include other forms of wood, such as hogged and chipped material, it may soon be possible to utilize profitably the large amount of sawmill residue produced in the Pacific Northwest.

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Manufacture and Use of Wood Flour

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Introduction

IF ONE were to trace back in history to the time when the saw was first used for producing lumber and other sawed wood products, he would find the original source of the fine wood particles, which for more than 50 years have been called wood flour. While the waste material produced from that first sawing operation was recognized as nothing but sawdust, it would have been possible, by drying the material and shaking it over a fine screen, of say 50 mesh, to obtain from the mass a very small percentage of fine wood particles which might have been designated as wood flour. The prevailing opinion is that the first use made of such fine sawdust was in Germany many years ago. It is reported that, during the first World War, some of it was used in cattle feed and even for human consumption in bread, due to the shortage of wheat.

Just when this finely pulverized wood was first called wood flour is anybody's guess, but its original use was undoubtedly on a very small scale and as a filler, which, in fact, has been its only use down through the years. It has also been referred to in the past as pulp or wood powder, but today it is most commonly known as wood flour.

As so little of this finely divided wood could be obtained from the original sawdust pile by screening, it became necessary to grind the whole mass. It is understood that the first attempts to pulverize the sawdust were by beating or hammering it down by hand. Later, with the coming of the machine age and the development of equipment much like that used in the grain mills, the mechanical production of wood flour was started with the old stone mills. Even today, wood flour is produced by this method in a number of small mills in Europe, in Norway, Sweden and Denmark; possibly a few mills of this type are still used in this country for making some grades of wood flour.

The first wood flour used in this country was imported and, even up to eight or ten years ago, there seemed to be a prevailing opinion that the foreign product was superior for some purposes to the quality produced in the United States. Through continued research and development, however, this impression has now changed.

Due to the fact that wood flour is used only as a filler, or as but one of the ingredients in many compounds where it is mixed with other materials, the average layman knows little or nothing about it. However, it has been rather extensively studied in numerous chemical laboratories throughout the country. This research has led to the establishment of technical specifications and quality standards to meet present requirements with the result that it is now impossible to utilize the sawdust from the piles found around most sawmills and allied operations. With the higher costs of oil and coal, moreover, this waste is often more valuable as fuel for the mill or plant.

Raw Material

For the first two years immediately following World War II, the demand for wood flour exceeded the domestic production, due chiefly to the scarcity of good raw materials for the industry. During this period, almost any kind or form of waste wood was used and quality standards were dropped until it was possible to screen out any old fines from the sawdust piles and call the resultant product wood flour. The consumers, struggling along from day to day on very short supply, were anxious to have some inventory on hand and encouraged new producers to install grinders and sifters to make wood flour from any waste. It soon developed,

however, that inventories began to be built up with wood flour of very poor quality.

The whole situation has now changed again, as the research and control laboratories have set up specifications much more stringent than ever before. Color, bulk or density, screen analysis, absorption value, fibrous structure, and resin and moisture content are all extremely important factors in producing a high quality wood flour to meet present-day requirements.

While various kinds of wood and types of wood waste have been used during the last few years to meet the extra heavy demand, it has now become necessary to make a very careful selection of raw material to meet present specifications and close tolerances. Even soft white pine, which has always made good wood flour, has to be selected as there are several different grades of this wood. Through research, it has been determined that the geographical conditions under which certain white pine is grown have much to do with its qualities for making good wood flour. It has been learned that, even with white pine, the wood from trees grown in one section of the country is much more desirable than that from another section. This is particularly true in meeting the specifications for absorption.

Manufacture

Because of the ever-present hazards of fire and explosion in the processing of wood flour, the manufacture of this product should not be attempted without a thorough investigation of the dangers involved in the different types of grinding and processing equipment. Many very costly failures have occurred, due to lack of experience and failure to take proper precautions with the equipment being used. Insurance rates covering this process are exceptionally high.

Some of the wood flour produced in this country is ground through *Stone Mills,* somewhat like the old burr stone mills used in the grinding of wheat, corn and other grains. Two large mill stones are used, one over the other, with grinding face usually horizontal. The bottom stone is stationary and the top one is revolved on a vertical shaft. The stones are totally enclosed, except for an opening at the center in the top through which the material to be ground is delivered to the stones, and an opening at the periphery of the stones from which the ground material is taken by air or conveyor.

Roller Mills are also used. These consist of two or more heavy steel rollers, made with steel teeth of varying degrees of fineness. The rollers usually work in pairs and are made to revolve in opposite directions. Several pairs of rollers are used one over the other, the material being fed to the top pair and dropped from one pair to the next lower in the series. These mills are also fully enclosed with feed spout at the top and outlet at the bottom.

The *Hammer Mill* is made with a heavy steel cylindrical and horizontal casing, with the bottom half firmly bolted to the base and the top half made so that it can be raised whenever it is necessary to work on the horizontal cylinder inside. The drive shaft passes through the center and the inside cylinder is made of heavy steel circular plates with spacers between, to which are attached steel plates that swing loosely and extend outward nearly to the inside wall of the casing enclosing the machine.

The *Beater Mill* is a more recent development and works somewhat like the hammer mill, except that it is constructed in an upright position with vertical shaft. To this shaft are attached staggered beaters, which whirl the raw material around and beat it until it passes through the screen which is a part of the casing.

The *Attrition Mill* is made with both single and double heads. The single-head type is made with one revolving disk and has the opposite disk stationary. The revolving disk is attached to the end of a horizontal shaft, which is also the motor shaft on direct motor-driven machines. The material to be ground is fed through the spokes at the center of the revolving disk and passes between the two disks which are set close together. The double-head type uses the same general principal, but with both disks revolving and in opposite directions. The disadvantage of this machine is that, like the stone mill, it has no screen in the machine itself; consequently more screening has to be done in the subsequent screening process.

Each of these machines will produce a different end product. Accordingly, in order to meet the exacting requirements of the differ-

ent consumers, it has become necessary that manufacturers use the several types of machines in separate departments.

With all types of grinding equipment, there is always the constant danger of dust explosions and fires, which usually start in the grinding mills. Magnetic separation will remove a percentage of the nails and other iron or steel items, small pieces of tin, and similar materials which may be present, but will not remove small bits of stone, flint, or non-magnetic metal.

Uses of Wood Flour

The principle uses of wood flour are in the manufacture of linoleum, plastics and explosives, which collectively consume approximately 80 to 85 percent of the total production in this country. The following partial list of other uses indicate the wide diversity of products in which wood flour is incorporated:

Composition floors
Rubber compounding
Artificial wood
Molded furniture
Ceramic brick
Storage battery cases
Wall paper
Plastic wood
Plaques
Hand cleaners
Fur cleaners

Molded Plastics Products, such as:

Bottle caps
Buttons
Ash trays
Cigarette cases
Billiard balls
Poker chips
Clock cases
Fountain pen desk sets
Gun grips
Picture frames
Gears
Radio cabinets and knobs
Telephone receivers
Auto steering wheels
Dashboard control knobs
Jewelry boxes
Camera cases
Smoking pipe racks
Fishing reels
Kitchen utensil handles
Molded lamp shades
Toys
Ornaments and carving
Door handles

Binders

As stated previously, wood flour is only a filler and some binder must be compounded with it, to hold it together when the combined materials are molded into any of the many different articles. The successful manufacture of these molded products, from small buttons to large turnings, is the result of extensive research and much experimental work on the part of the many producers.

The following is a partial list of binders which have been used successfully in various processes:

Resins
- Phenolic resins
- Natural resins
- Fossil resins

Minerals
- Calcium silicate
- Calcium sulphite
- Sulphur

Glues
- Blood Albumin
- Bone
- Casein
- Fish
- Hide

Miscellaneous
- Linseed oil
- Asphalt
- Bituminous
- Dextrin
- Sodium silicate
- Shellac
- Lacquer
- Core oils
- Pitch
- Distilling wastes
- Cellulose acetate of cellulose nitrate in anylacetate (mixture of acetone)
- Celluloid dissolved in acetone
- Incense

Compounding

The percentages of wood flour, used as a filler in the many different compositions in which it becomes a part, will vary from as low as five or ten percent to as high as 60 or 70 percent. Due to its low cost in comparison with the other ingredients of the mixture, it is, in most cases, desirable to use as large a percentage of wood flour as possible; on the other hand, the allowable percentage depends entirely on the finish, strength and other qualities desired in the finished article. In plastics, an increase in the percentage of wood flour will usually give increased strength to the molded article, but the surface finish of the product may have less luster and not be quite as smooth as when a smaller percentage of wood flour is used.

While wood flour is usually sold on the basis of screen analysis, that is not always the most important factor in determining its suitability in certain compounds. It is a very fibrous material and rather difficult to screen finer than 100 mesh. Provided the wood flour has a high absorption value, so that it will completely absorb the binder, dye and other ingredients and better become a part of the whole mixture, the longer fibers are much more desirable for adding strength in some articles.

Development of the Industry

The production of wood flour in this country has had only a normal growth during the past 15 to 20 years. With the exception of the two years immediately following World War II, when there was a short supply, domestic pro-

duction has kept pace with the demands of the industries in which it is used.

Prior to 1940, imports averaged approximately 20 percent of the total wood flour used in this country, but the percentage of imports was gradually falling off and domestic production was increasing. During the War, there were no imports of any consequence and domestic production equaled the demand.

Wood flour is usually sold by the ton and the price today varies from $20.00 per ton for the coarser grades, to $40.00 per ton for the finer grades (approximately 100 mesh). A small percentage of very fine (200-mesh or finer) material is sold at higher prices, usually for special work. In 1930 approximately 35,000 tons per year were consumed in this country; in 1947 the consumption was 75,000 to 80,000 tons.

The development of the wood-flour industry in the United States in the next few years may be expected to continue its present course, with a gradual expansion as the normal demand increases, unless over-expansion occurs in Canadian production and results in severe competition. The possibility of any displacement of this product by mineral or other organic fillers at lower prices is rather slight, although some minor shifts may occur where other fillers provide special qualities. Since almost all wood flour is used as a secondary material in the products into which it goes, the general conditions of the wood-flour industry should parallel those of the consuming industries.

Barring a general economic decline, the wide diversity of products into which wood flour enters should guarantee a fairly reasonable degree of stability for the industry.

FOREST PRODUCTS RESEARCH SOCIETY

Dimensional Stability of Synthetic Board Materials Used As Core Stock

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A preliminary study was made by the U. S. Forest Products Laboratory to determine some of the factors that have an influence on the dimensional stability of veneer- or plywood-faced panels using synthetic board materials as core stock. Variables included in the study were fiber size, fiber-to-binder ratio, core-stock density, treatment with drying oil, face construction, and core construction.

The various types of core materials were evaluated on the basis of bending tests and swelling and recovery data obtained after complete water immersion. The results indicated that neither fiber size nor fiber-to-binder ratio, in the ranges studied, had any noticeable effect on dimensional stability. Treatment of fibrous core stocks with drying oil resulted in a considerable increase in bending strength and greatly reduced the amount of springback or recovery following water immersion. Although the rate of swelling was retarded by oil treatment, swelling equilibrium was not affected. The most suitable core-density range was found to be between 0.4 and 0.7.

Core-stock panels with plywood and veneer faces were evaluated on the basis of both swelling and recovery data and visual defects, such as checking, warping, delamination, etc., following cyclic exposure to high and low relative humidity conditions. Two- and three-ply cross-banded faces were found to give much more stable panels than single veneer faces. With proper spacing, edge-grain core material gave panels that had very low swelling and recovery values.

In all core materials thus far studied a maximum recovery was reached on exposure to high humidity conditions, after which flat-grain cores had approximately the same degree of swelling as normal wood. Pre-humidification was suggested as a means of preventing ridges or other visible lines of demarcation on the faces of panels having a combination of solid wood and synthetic wood core.

Introduction

SYNTHETIC board materials are being utilized to an ever increasing extent in the building industries. They now are used not only as insulating and decorative wall boards, but also as a filler or core for plywood- or veneer-faced panels used in interior paneling, flush doors, furniture, cabinet work, etc. It was thus thought desirable that the U. S. Forest Products Laboratory obtain more information about the various factors that may have an influence on the dimensional stability of this type of core material, particularly where it is used in panels having a core made of a combination of solid wood and synthetic wood.

Appreciable differences in the rate or extent of swelling or any tendency for unequal spring-back or recovery between the solid and synthetic wood cores will lead to warping and twisting, to visible lines of demarcation between the two materials, or to actual cracking and checking of the faces over the transition areas. Any of these defects will result in unsalable products, if the change occurs during storage on the dealer's display floor, or in customer dissatisfaction if it occurs after purchase.

Variables included in the present study were: Fiber size, fiber-to-binder ratio, core density, effect of drying-oil treatment, and face and core construction. All tests were evaluated on the ability of experimental panels to stand up under complete water immersion and cyclic exposure to high and low humidities. Micrometer measurements were made to determine the extent of swelling and recovery, and the panels were rated by visual inspection for resistance to checking, warping, delamination, etc.

Materials Used

All core stock material used in the preparation of test panels consisted of a coarse fiber fraction, usually hogged mill-waste further processed to the desired fineness in an attrition

[1] Maintained at Madison 5, Wisconsin, in cooperation with the University of Wisconsin.

mill, and varying amounts of a more highly refined cellulosic material, such as milled newsprint or semichemical pulp, as a binder. Fiber and binder were diluted with water to about two percent consistency, and three percent of paper-makers rosin-alum size was added with continuous agitation. The resultant slurry was then formed into a wet lap on a screen box and dried in a hot press under the desired pressure. So-called "replacement" linseed oil was used in the oil-treating study. For those cores in which low oil uptake was desired, the original oil was diluted with mineral spirits. After air-drying to remove the volatile solvents, the treated cores were cured in an oven for 24 hours at 212° F. (100° C.) to 230° F. (110.C).

All panel faces were of yellow birch veneer and face thickness was held to about 1/16 inch. The single-ply faces were cut from 1/16-inch veneer, and the two- and three-ply cross-banded faces were made from 1/32-inch veneer. All bonding was done with a high-temperature-setting phenolic resin glue.

Preliminary Study

Effect of Fiber Size, Fiber-binder Ratio, and Density on Dimensional Stability

In a preliminary study, to determine the effect on dimensional stability of fiber size, fiber-binder ratio, and board density, a series of 21 panels was prepared using a mixed fiber-newsprint binder combination. Fiber size varied from that produced with an attrition mill plate clearance of 0.0025 inch to a plate clearance of 0.0075 inch, and fiber-to-binder ratios ranged from 90 percent fiber and 10 percent binder to 60 percent fiber and 40 percent binder. Board weight was held to 300 grams (10- by 10-inch forming box) and the wet lap was dried under conditions ranging from oven drying to press drying at 25, 50, and 150 pounds per square inch (0.4 to 0.9 specific gravity).

The completed panels were faced on both sides with two-ply, 1/32-inch, cross-banded birch veneer through which 3/32-inch holes were drilled at about 2-inch spacings to facilitate moisture pickup. After oven-drying for 48 hours, the panels were placed in the 80° F. and 97 percent relative humidity room for seven days. Cycling was continued until thickness equilibrium was attained, or until face-core delamination became too great for accurate thickness determination. Micrometer measurements of the panel thickness were made after each phase of the cycling process.

Swelling and recovery equilibrium was essentially attained at the end of four cycles. Recovery or spring-back values ranged from 6 to 10 percent, with no apparent dependency on fiber size or fiber-to-binder ratio, but increased slightly with increasing board density. Sixty to seventy percent of the total recovery was obtained at the end of the first cycle, 75 to 85 percent at the end of the second cycle, and 90 to 100 percent after the third cycle. After cycling, the equilibrium swelling of all panels between oven-dry and 97 percent relative humidity was about 7 to 8 percent.

The panels having cores of higher density (above 0.6 to 0.7) showed a greater tendency toward separation of face and core and also were more subject to core checking. There was no visible influence due to fiber size or fiber-to-binder ratio.

Effect of Oil Treatment on Dimensional Stability

In order to gain an idea of the possible improvement in the relative strength and moisture resistance imparted by drying oils, a series of hardboards of two different densities was prepared. After trimming, the boards were dipped in linseed oil diluted so as to give the desired oil content, air-dried for several days to remove excess solvent, and then heated for 24 hours at 221° F. (105° C.) to polymerize the oil. Static-bending specimens 1½ inches wide by 8 inches long and moisture-absorption specimens (1⅛ by 6 inches) were cut from each panel. The moisture-absorption specimens were immersed in water for 24 hours, after which swelling and uptake values were determined. After oven redrying, the extent of recovery or springback was determined. Table 1 gives the results obtained.

From the table it may be seen that drying-oil treatment has a great influence on bending strengths of fibrous board materials, more than doubling the values of untreated boards at the higher oil contents. Moisture absorption and swelling values obtained after 24 hours' water

TABLE 1.—EFFECT OF OIL TREATMENT ON STRENGTH AND MOISTURE RESISTANCE

Board No. (1)	Forming pressure (2) Lb. per sq. in.	Cured oil content (3) Percent	Specific gravity (4)	Modulus of rupture (5) Lb. per sq. in.	Specific modulus[1] (6)	24-hour water absorption (7) Percent	24-hour water swelling (8) Percent	Recovery (9) Percent
1 and 2	100	21.6	0.85	5,780	6,800	21.0	9.5	1.2
3 and 4	100	9.3	.79	5,150	6,530	28.0	15.0	2.8
5 and 6	100	4.7	.73	4,450	6,090	28.0	16.3	4.4
7 and 8	100	.0	.66	1,900	2,880	81.0	37.9	19.2
9 and 10	200	14.2	.98	7,800	7,970	20.0	13.1	2.7
11 and 12	200	11.1	.91	6,790	7,450	27.0	16.1	3.5
13 and 14	200	9.0	.93	6,560	7,060	27.0	17.1	4.3
15 and 16	200	.0	.86	3,220	3,750	65.0	37.1	17.0

[1] Ratio of modulus of rupture to specific gravity.

immersion again show a considerable improvement due to oil impregnation. A still greater influence is shown on the recovery or springback values obtained following redrying after water immersion, where an eight- to ninefold range is covered. Part of the influence on moisture absorption and swelling may be due to a slowing down in the rate of moisture pickup; that is, equilibrium, swelling, and absorption values may not be greatly influenced by oil treatment. This was shown to be the case in later studies.

Effect of Core Construction

With the idea that most of the springback of a fibrous board tends to occur in the direction in which the compression was applied during formation, it was thought that a panel in which the core material was placed on edge would have a very low recovery and might prove especially desirable in panels using a combination of solid wood and synthetic wood. Accordingly, an approach was made to this problem by fabricating two plywood-faced panels as follows:

Two matched hardboard sheets were prepared using 80 percent fiber and 20 percent newsprint binder. One sheet was cut in half, glued on the screen faces, and pressed at 150 pounds per square inch for 20 minutes at 310° F. (154.4° C.) giving a board with a ½-inch core. Two-ply, cross-banded, 1/32-inch birch faces were glued on each side. The second sheet was cut into ⅜-inch wide strips, which were then glued on both faces and edges with a low-temperature-setting resorcinol glue and assembled into a core panel with the edges of the strips forming the faces of the core. The strips were clamped tightly together and, after two-ply birch faces were placed on each side, the entire assembly was put in a screw press overnight.

The completed panels were trimmed to 4½ by 8 inches, and ⅛-inch holes were drilled at 1-inch spacings to facilitate moisture uptake. Following this, the panels were oven dried, measured in thickness with a dial gage, and placed in a room at 97 percent relative humidity for seven days. Two such cycles were made and, while they were not quite sufficient to allow the panels to reach equilibrium conditions, the data in Table 2 point out very well the differences in swelling and recovery of the two types of cores.

TABLE 2.—INFLUENCE OF CORE CONSTRUCTION ON DIMENSIONAL CHANGES

Type of panel (1)	Swelling (oven-dry to 97 percent relative humidity) (2) Percent	Recovery (2 cycles) (3) Percent
Flat grain panel	9.4	7.6
Edge grain panel	3.1	.4

Thus, for applications where only a small amount of core swelling can be tolerated, edge-grain core stock appears to be most suitable, since it swells only about one-third as much as the flat-grain stock and shows almost no recovery in the thickness direction. Normal swelling does occur in the width direction, however, and this panel showed considerable core-to-face separation along the glue line, with the result that the core became about ½ inch wider than the faces. This excessive side growth might have been prevented, if the core strips had been only loosely packed or if they had been spaced about 1/16 to ⅛ inch apart. Under these conditions recovery should largely take place internally.

Detailed Study of the Effect of Face and Core Stock Characteristics on Dimensional Stability

With the results of the preceding studies as a background, it was decided to make a more thorough study on the effect of face and core construction on the dimensional stability of synthetic board materials. In order to secure reasonably good panel matching, the same batch of raw fiber and binder was used for all panels. Variables included in the study were as follows:

(1) core density
(2) core construction
  (a) flat grain
  (b) edge grain
    (1) close packed strips
    (2) spaced strips
(3) tempering oil treatment to various oil contents
(4) face construction
  (a) one-, two-, and three-ply veneer faces

Preparation of Panels for Test

(1) Core Stock

A total of 108 12-inch square core-stock panels were prepared; 27 panels were formed at 5 pounds per square inch pressure, 27 at 25 pounds per square inch, 27 at 50 pounds per square inch, and 27 at 250 pounds per square inch. These test panels were cut from 4- by 4-foot boards, two of which were made at each pressing condition.

In making the 4-foot boards, raw cold-milled cottonwood fiber was combined with two percent cold-milled newsprint and sized with a three percent rosin-alum size. The thoroughly mixed slurry at about two percent consistency was evenly distributed in a 4-foot screen box and a wet mat formed by suction removal of the water. The wet mat was transferred to a hydraulic press, given a cold squeeze to remove a large portion of the water, and then press dried at 180° C. for about one hour under the desired pressure. Each 4-foot mat was of approximately the same original fiber weight, so that the final dried panels were of different thicknesses depending on the applied pressure.

(2) Oil Treatment

Eighteen panels in each density group were treated with a drying oil (linseed oil); nine panels were dipped in oil of about 10 percent solids content and nine panels in oil of about 20 percent solids content. The time of oil immersion was varied so as to secure a total solution uptake approximately equal to the untreated board weight. After treating, the panels were stored in a closed container for two days to allow diffusion of the oil to take place; then the panels were stickered and allowed to air dry for two weeks to remove excess solvent, following which the oil was further cured by oven drying 24 hours at 230° F. (110° C.).

(3) Face Material

All two- and three-ply face material was made from 1/32-inch, rotary-cut, sap yellow birch veneer of cross-banded construction, assembled and pressed into sheets prior to use. Single-ply faces were cut from 1/16-inch sap yellow birch.

(4) Panel Assembly

(a) Flat-grain panels. — Nine panels were made in each range of core density in which core material was used in the normal flat-grain manner, giving a total of 36 flat-grain panels. Three panels in each range were untreated, three were treated with 10 percent drying oil, and three were treated with 20 percent drying oil. Of the three panels in each oil-content category, one was faced both sides with a one-ply face, one with a two-ply face, and the third with a three-ply face.

In assembling the panels, both cores and faces were glued with a hot-setting phenolic glue, air dried 24 hours to remove glue solvent, and then pressed at 310° F. (154.4° C.) for ten minutes, using pressures which gave no more than five percent compression or a maximum pressure of 150 pounds per square inch for those cores that were originally formed at 250 pounds per square inch.

(b) Edge-grain panels. — The remaining 72 core-stock panels were all cut into ½-inch wide strips. Nine faced panels in each density group of the three oil-content categories were made in which the core strips were placed on edge and kept in close contact (no clamping) with each other during application of the faces.

In the remaining nine panels of each density group the core strips were spaced 1/16 inch apart by inserting small splints of 1/16-inch veneer between the ends of the strips. The splints were short enough so that they were removed during subsequent trimming. Gluing, facing, and pressing conditions were the same as those followed for the flat-grain panels.

The construction of the various types of test panels is shown in Figure 1.

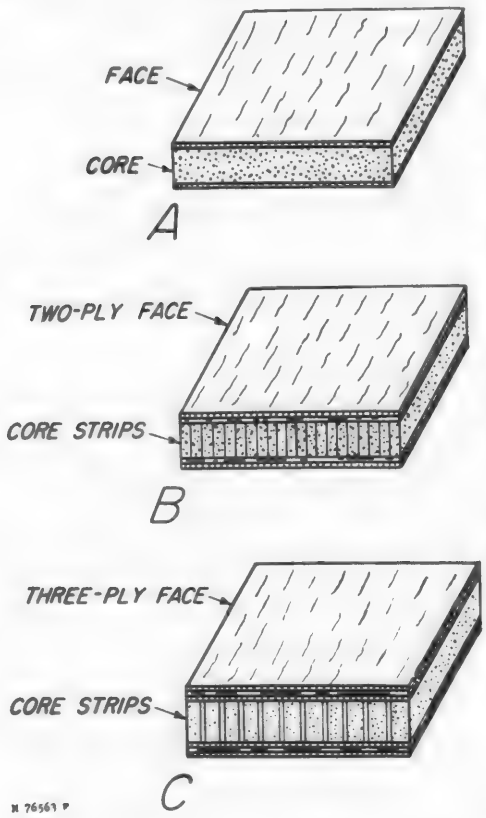

Fig. 1.—Construction of panels for tests of dimensional stability of synthetic board materials used as core stock. *A*, flat-grain panel with one-ply veneer faces; *B*, close-packed, edge-grain panel with two-ply faces; and *C*, spaced edge-grain panel with three-ply faces.

Test Procedure for Core-stock Material

(a) Static Bending

Relative bending strengths of the various core-stock materials used in this study were determined on a home-made static bending apparatus. Test specimens were supported on cross bars using a 16-to-1 span-depth ratio. Center loading was applied through constant addition of lead shot to a bucket freely suspended from the center of the specimen until failure occurred. Specimen width was either 1 or 1½ inches, depending on the capacity of the apparatus and the strength of the specimen. Breaking loads were determined from the weight of the bucket plus added shot, and moduli of rupture were calculated from these values, the dimensions of the specimen, and the span used.

(b) Water Immersion

Six core stock specimens from each density and oil-content group were cut from the ends of the bending specimens (specimen size = 5 inches by 1 inch by thickness). After oven drying for 24 hours at 221° F. (105° C.), the specimens were weighed, measured in thickness with a dial gage, and immersed in water. Twenty-four hour water absorption measurements were made, following which the specimens were allowed to soak for 20 days in order to reach swelling equilibrium and again measured. A final thickness measurement was made after oven redrying.

From the gain in thickness attained during the 20-day soaking period, swelling-plus-recovery values were determined. Recovery, or springback, values were determined from the thickness gain between the original and final oven-dry conditions. Subtracting the latter from the swelling-plus-recovery values gives the amount of swelling alone.

Table 3 summarizes the test results.

Test Procedure for Faced Panels

(a) Cyclic Exposure

The 108 plywood- and veneer-faced panels were trimmed to a 9-inch length and to a 7-inch width where possible. Those panels having a high-density core stock of close-packed, edge-grain construction could only be made in narrower widths due to lack of material. All panels were oven dried for 48 hours at 221° F. (105° C.) and then weighed and measured in both thickness and width. Thickness measurements were made at ten positions over the panel faces and the average value used. After

TABLE 3.—SUMMARY OF TEST DATA ON CORE STOCK

Core-forming pressure (1) Lb. per sq. in.	Drying off content (2) Percent	Specific gravity of core (3)	Modulus of rupture (4) Lb. per sq. in.	Specific modulus[1] (5) Lb. per sq. in.	24-hour water absorption (6) Percent	Equilibrium swelling (7) Percent	Recovery (8) Percent
	0	0.31	358	1, 155	73.3	9.6	3.5
5	10	.34	510	1, 500	47.6	10.1	.3
	20	.39	775	1, 990	48.4	9.2	.3
	0	.46	818	1, 780	58.1	14.7	5.2
25	10	.56	1, 664	2, 970	35.9	13.6	2.3
	20	.56	2, 243	4, 000	36.0	14.2	1.1
	0	.56	1, 358	2, 420	93.2	18.5	9.9
55	10	.61	2, 295	3, 760	37.8	15.7	4.8
	20	.72	2, 750	3, 820	27.8	15.2	1.9
	0	.94	4, 087	4, 350	70.5	30.5	17.0
250	10	.90	5, 440	6, 050	26.1	20.4	4.4
	20	1.00	4, 768	4, 768	13.7	17.9	1.6

[1] Ratio of modulus of rupture to specific gravity.

measurements were made, the panels were piled on stickers and stored in a room at 80° F. and 90 percent relative humidity for one month under good air circulation conditions. Weight, thickness, and width measurements were made on the conditioned panels and again after 48 hours oven drying at 221° F. (105° C.). The panels were then returned to the 90 percent humidity room and cyclying was continued. A total of four complete cycles were given, with complete data taken at each stage of the cycle. From the data obtained, swelling in width and thickness and recovery in width and thickness were determined for each type of panel construction. Visual inspection, during and after cycling was used to obtain a relative evaluation of the various panels.

Table 4 summarizes the test results.

Results and Discussion

Tests on Core Material

From columns 4 and 5 of Table 3, it is again evident that drying-oil treatment greatly improves the bending strength of fibrous-core materials, especially in the lower density range. In this range the addition of ten percent oil has about the same effect on the specific modulus as increasing the density by approximately 0.1.

Twenty-four hour moisture takeup is not greatly influenced by board density, but is considerably reduced by oil treatment, probably due to a water-repellent action of the oil.

Equilibrium swelling values (column 7) become larger in almost direct proportion to board density, that is, doubling board density changed the swelling from 9.6 to 18.5 percent, while tripling the density increased the swelling to 30.5 percent. Oil treatment did not appear to have much effect on swelling equilibrium, except on the high-density hardboard, indicating that drying oils do not impart permanent antishrink properties.

Recovery, or springback, increased considerably with increasing core density. Oil treatment had a marked effect on reducing recovery, indicating that the oil film surrounding the fibers is a rather effective bonding agent.

Tests on Assembled Panels

Columns 7, 8, and 9 of Table 4 summarize the values found for the swelling of the various panels on going from oven dryness to a relative humidity of 90 percent. Neither density nor oil treatment seem to have much influence on swelling equilibrium, a result which is quite different from that found for equilibrium water swelling, where the degree of swelling was directly dependent on core density. Apparently the fiber-bonding strength of newsprint binder is capable of restraining excessive swelling of higher density core material as long as the moisture content remains below fiber-saturation point, but loses some of this restraining or binding capacity above this point. Edge-grain core stock panels show only one-fourth to one-third the swelling of flat-grain panels, a conclusion reached in the preliminary work and a valuable asset for panels that have to meet minimum swelling requirements. There seems to be a definite tendency for panels with three-ply faces to exhibit a slightly greater swelling than panels with either two-

TABLE 4.—SUMMARY OF TEST DATA ON FACED PANELS

Core-forming pressure (1) Lb. per sq. in.	Number of face plies (2)	Core construction (3)	Specific gravity of faced panels: Controls (4)	Specific gravity of faced panels: 10 percent oil (5)	Specific gravity of faced panels: 20 percent oil (6)	Equilibrium swelling—oven dry to 90 percent relative humidity: Controls (7)	Equilibrium swelling—oven dry to 90 percent relative humidity: 10 percent oil (8)	Equilibrium swelling—oven dry to 90 percent relative humidity: 20 percent oil (9)	Swelling in width—oven dry to 90 percent relative humidity: Controls (10)	Swelling in width—oven dry to 90 percent relative humidity: 10 percent oil (11)	Swelling in width—oven dry to 90 percent relative humidity: 20 percent oil (12)	Total recovery (4 cycles) in thickness: Controls (13)	Total recovery (4 cycles) in thickness: 10 percent oil (14)	Total recovery (4 cycles) in thickness: 20 percent oil (15)	Panel condition after 4 cycles[1]: Controls (16)	Panel condition after 4 cycles[1]: 10 percent oil (17)	Panel condition after 4 cycles[1]: 20 percent oil (18)
	1	Flat	0.41	0.44	0.47	5.06	4.97	4.10	2.30	2.14	2.14	4.47	5.95	3.60	VP	VP	VP
	2	----do----	.41	.43	.48	5.70	5.25	4.57	.42	.42	.28	4.13	5.90	3.93	G	G	G
	3	----do----	.45	.45	.50	5.80	5.16	4.62	.42	.42	.42	3.77	4.47	4.03	G	G	G
	1	Edge-tight	.44	.43	.47	1.88	1.70	1.62	4.60	4.30	4.90	1.21	1.55	1.14	F	VP	F
5	2	----do----	.44	.42	.46	2.14	2.24	1.82	.59	.45	.30	1.62	1.57	1.34	G	G	G
	3	----do----	.44	.44	.47	2.08	2.16	1.81	.45	.45	.30	1.13	.94	.91	G	G	G
	1	Edge-spaced	.41	.40	.46	1.93	1.72	1.48	4.90	4.60	5.35	2.71	1.75	1.17	F	F	F
	2	----do----	.40	.40	.42	2.40	2.05	1.69	.59	.45	.30	3.44	1.21	1.20	F	G	G
	3	----do----	.41	.43	.44	2.07	2.51	1.85	.59	.45	.30	.96	1.43	.77	G	G	G
	1	Flat	.56	.59	.61	5.30	6.36	5.28	1.85	1.71	1.42	4.24	2.96	3.57	VP	P	VP
	2	----do----	.53	.58	.60	6.10	6.35	5.58	.42	.42	.42	3.58	2.83	2.76	G	G	G
	3	----do----	.56	.60	.64	5.70	5.58	5.36	.42	.42	.42	3.24	2.68	2.85	G	G	G
	1	Edge-tight	.51	.55	.59	1.42	1.44	1.60	4.70	4.08	4.81	.32	.16	.48	P	F	F
25	2	----do----	.51	.55	.57	1.58	1.59	1.64	.60	.45	.15	.16	.00	.33	G	G	G
	3	----do----	.55	.57	.58	2.02	2.06	1.66	.45	.45	.30	.29	.30	.45	G	G	G
	1	Edge-spaced	.47	.47	.52	1.42	1.44	1.62	4.70	4.42	5.14	.32	.32	.65	P	F	G
	2	----do----	.46	.47	.51	1.74	1.75	1.64	.45	.30	.30	.48	.32	.50	G	G	G
	3	----do----	.49	.49	.55	2.17	2.06	2.11	.45	.30	.45	.29	.44	.30	G	G	G
	1	Flat	.61	.64	.72	5.73	5.45	4.64	2.00	1.56	1.14	5.07	4.26	4.61	VP	P	P
	2	----do----	.64	.63	.75	6.06	6.16	5.23	.42	.42	.42	5.40	3.92	3.19	G	G	G
	3	----do----	.65	.66	.70	6.72	6.32	5.62	.42	.42	.42	4.04	3.52	2.67	G	G	G
	1	Edge-tight	.59	.59	.71	1.41	1.44	1.76	3.90	4.13	4.40	.00	.32	.16	F	F	F
50	2	----do----	.59	.63	.69	1.56	1.76	1.46	.71	.53	.35	.31	.32	.49	G	G	G
	3	----do----	.61	.60	.70	2.01	1.89	1.65	.35	.53	.53	.29	.29	.45	G	G	G
	1	Edge-spaced	.48	.53	.59	1.57	1.60	1.60	4.60	4.41	4.85	.47	.32	.65	F	F	F
	2	----do----	.51	.53	.59	1.72	1.75	1.64	.45	.30	.30	.16	.16	.49	G	G	G
	3	----do----	.51	.57	.59	2.31	2.19	1.94	.45	.45	.30	.14	.15	.60	G	G	G
	1	Flat	.91	.89	.93	6.34	4.84	5.08	1.00	1.00	1.28	4.90	5.45	4.05	VP	VP	VP
	2	----do----	.86	.86	.95	7.40	6.37	6.24	.42	.42	.28	4.93	4.68	3.88	F	F	P
	3	----do----	.88	.83	.91	6.43	6.22	5.63	.56	.42	.28	3.47	2.78	3.31	F	F	VP
	1	Edge-tight	.88	.82	.96	1.41	1.47	1.95	3.10	3.08	4.00	.00	.00	.00	F	F	P
250	2	----do----	.81	.85	.97	1.40	1.72	1.64	.94	.94	.62	.16	.17	.33	G	G	P
	3	----do----	.86	.88	.96	2.14	1.88	1.97	.62	.94	.62	.29	.93	.30	G	G	P
	1	Edge-spaced	.60	.69	.77	1.71	1.93	1.82	4.70	4.50	4.73	.47	.53	.33	G	F	F
	2	----do----	.64	.68	.74	1.70	1.70	1.96	.22	.22	.22	.62	.69	.00	G	G	G
	3	----do----	.64	.72	.74	2.15	2.32	1.95	.22	.44	.22	.43	.31	.15	G	G	G

[1]Symbols

VP—very poor—severe core and/or face checking, warping, ridging, discoloration.
P —poor —moderate.
F —fair —slight.
G —good —no face or core checking, none to slight warping, no ridging or discoloration (generally satisfactory).

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ply or single-ply veneer faces. This may be due to the greater thickness of normal wood, which may have a higher degree of swelling than this particular type of core material.

Swelling-in-width values are shown in columns 10, 11, and 12 of Table 4. Results again indicate that oil treatment has little effect on swelling equilibrium. Small decreases in sidewise swelling were obtained with increasing core density, but the major factor influencing swelling in this direction appeared to be the type of construction used in the faces and cores. Single-ply veneer faces offered little restraint to sidewise swelling, and the maximum swelling of panels thus faced was two to ten times that of panels having cross-banded face plies. Panels with veneer faces and edge-grain cores showed an additional two- to three-fold swelling over flat-grain panels of the same face construction.

Total recovery values listed in columns 13, 14, and 15 of Table 4 reflect not only recovery from the original core-board forming-pressure, but also a certain amount of recovery from the variable compression given during face bonding. This latter factor may explain the somewhat high values obtained on the edge-grain, low-density core panels. In contrast to the results obtained on equilibrium water swelling, recoveries of the panels exposed to 90 percent relative humidity conditions were not appreciably influenced by core density or by oil treatment. As explained previously, this may be due to the restraining action of the binder at moisture contents below fiber saturation. Recoveries of edge-grain cores were generally less than ½ percent in the thickness direction. Panel measurements made after final oven drying gave practically zero recovery in width, indicating that as long as the edge-grain core strips are not tightly clamped, as was done in the preliminary test on ede-grain cores, any recovery in width will take place internally.

Results of relative panel ratings as determined by visual inspection are given in columns 16, 17, and 18. The ratings indicate that two- and three-ply cross-banded faces were greatly superior to single-ply veneer faces, that the most suitable density range for core stocks lies below 0.7, and that drying-oil treatment has no effect on over-all panel performance insofar as warping and checking are concerned.

Summary

Preliminary tests were made on the moisture stability of panels having plywood and veneer faces and cores made from a fibrous wood-waste board material. Among the variables studied were: Fiber size, fiber-to-binder ratio, core stock density, drying oil treatment, and face and core construction. Evaluation of the various types of boards was made from complete water immersion tests, bending strength tests, and high to low humidity cycling tests. From the data obtained, the following general conclusions were reached:

(1) In the ranges studied, neither fiber size nor fiber-binder ratio had any noticeable effect on the stability of the core stock.

(2) The most suitable density range of the core stock, from the standpoint of dimensional stability, appears to lie between 0.4 and 0.7 gram per cubic centimeter.

(3) Drying-oil treatment is of considerable benefit in increasing the bending strength of fibrous core materials and greatly reduces the extent of springback or recovery following water immersion. It has little effect on swelling equilibrium, whether by water immersion or by exposure to high relative humidities, but does retard the rate of swelling.

(4) Single veneer sheets are not suitable face material. Faces should be of two- or three-ply cross-banded construction, and for balanced construction the same faces should be applied to both sides of the core.

(5) Edge-grain core-stock panels exhibit considerably lower swelling and springback values than flat-grain panels. To prevent excessive sidewise swelling of edge-grain cores, the core strips should not be tightly packed during panel assembly.

(6) One of the most important factors determined from the present study, from the standpoint of using fibrous core materials in combination with normal wood for panel manufacture, is that all of the core materials studied reached a maximum recovery value on exposure to moisture and thereafter exhibited

a relatively constant degree of swelling at any given humidity condition. In the case of flat-grain core panels, this swelling was about the same as the swelling for normal wood. If then, in panels utilizing a combination of fibrous and normal wood core, the fibrous cores were to be conditioned prior to panel assembly so as to remove this springback, no difficulty should be experienced with differential swelling between the two core materials and no zone of demarcation should be apparent. Conditioning could be done at high relative humidities or possibly by water immersion, to give a definite moisture pickup just after pressing. The dipped panels, after close stacking for a day or so to allow moisture equalization, could be redried in a kiln or by air drying and then used.

In order to supplement the conclusions reached in this study on the moisture stability of fibrous core materials, further tests should be made on larger commercial-sized panels; and particularly cyclic exposure studies on panels having a combination solid and synthetic wood core. Tests should include dry-formed boards as well as wet-formed, and additional information is also needed on the most suitable procedures to use for preconditioning core stock materials, especially by water immersion, since this appears to be a faster, more convenient method than by extended high humidity conditioning.

Discussion

Prof. E. George Stern (Virginia Polytechnic Institute): One of the prime uses of the described waste-core boards may be for furniture panels. It would be of interest to learn of any performance data concerning the minimum density requirements for core material in furniture panels. If the core is too light, its compressibility may be too high to withstand rigidity requirements for furniture panels, as obtained with conventional lumber cores.

Many furniture manufacturers are confronted with the fact that, upon exposure of their highly finished production items, the core gluelines show through the cross- and face-veneers. It is believed that the use of spaced edge-grain core-stock strips results in the appearance of joint lines on highly polished surfaces, if conventional veneer thicknesses for crossbands and faces are used. Are data available on the minimum thicknesses for cross- and face-veneers of various commercial wood species, which prevent such undesirable appearance of core-joint lines through highly polished faces upon exposure to high humidity for a reasonable long time?

Warping and cupping of waste-core furniture panels of large sizes are undesirable features of some of these panels. Comparative data on the stability of various types of core construction would be welcome.

FOREST PRODUCTS RESEARCH SOCIETY

Precision Surfacing of Wood

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THE surfacing of wood is an old process, stemming from the early days with their hand work and crude tools and marked by the later transition to simple machines with revolving cutterheads. Less than a century ago, the wood planer, or surfacer, was developed. The power to turn the cutterhead was the steam engine or water wheel, and the transmission was the leather belt.

It is only within the last 40 years that real progress has been made in precision planing: From leather and composition to V-belts; from babbitt and bronze friction bearings to anti-friction ball and roller bearings; from the thick carbon-steel, slotted knives to the thin high-speed, Tungsten-tempered knives. Electric motor development and refined oils and greases have also played an important part. We have done some planing with carboloy knives, but these are as yet largely in the experimental stage.

In the support of precision planing, or surfacing, of wood, this paper will deal only with what is sometimes called "cabinet surfacing."

The machines employed average 30 to 36 inches in width, with a bed drop of six to eight inches on inclined ways. The cutterheads will average five inches, not more than six inches in diameter, and carry four to six high-speed steel knives.

The first requisite is a heavy, rigid machine on a firm foundation. It is very important that the foundation be solid and unchanging. Concrete in solid ground is best. A machine of cast iron or semi-steel frame construction will absorb the vibration of the knives contacting the surface of the wood. The material to be planed must pass over a rigid, hardened bed at a positive and, above all, a uniform rate of feed. The upper rolls and pressure bars must hold the material firmly to the bed.

In the early days, square heads were used, and the cutting angle of the knives was 45°. The speed of the head was 4200 rpm. When round cutterheads and thin knives came into use, the heads were milled for a 30° cutting angle of the knives.

When the motor on the arbor was applied, it slowed the cutterhead speed to 3450 rpm. In conjunction with the slower head speed, the cutting angle was reduced to 20°, to avoid tearing or lifting the grain of the wood. This lower cutting angle of the knife had two faults in practice. More pressure and power was required to feed the material, and knife heel developed more quickly. Knife heel not only breaks and hammers the wood cells and fibre, but sets up vibration. With the development of motor-driven grinders and jointers, to true the knives and grind them in the machine, the cutting angle was increased to 25°. For many years, 25° has been the standard cutting angle of the knives with our firm. This cutting angle will successfully surface 95 percent of all types and kinds of hard and soft woods, narrow pieces, or glued-up panels.

The knife projection from the bar lip should not exceed 3/32 inch, nor should it be much less than 1/16 inch. The lip bar under the knife bends and breaks the wood chips. The chipbreaker in front of the cutterhead performs more of a mission of holding the stock solid to the bed, than of breaking chips.

In all cabinet, or finishing, planing there is a practical limit of 50 or 55 feet per minute for the rate of feed at which material can be handled and have lapped or butted stock passing through the machine. Also, the roll and bar positions limit the diameter of the cutterhead; and for strength or stiffness, and practical maintenance, four-knife heads are universally used. Thus, within these limits there

is a close relation between the feed rate and the number of knife cuts per inch.

With the maximum full-load attainable speed of 3450 rpm., using a two-pole motor on a 60-cycle current, only 13,800 knife cuts are produced per minute. This limits the rate of feed to between 30 and 45 feet per minute to get a good finish—smooth, no pronounced knife or revolution marks, no tearing or grain lifting, nor, on the other hand, a glazed or hammered surface.

To increase production, the cycle of the current is increased. Motor on the arbor cutterheads will turn successfully at 4,000; 5,000; or 6,000 rpm.

For many years, bearings have been precision made with vibrationless composition ball retainers—preloaded for heavy duty and close work; cutterheads, being of small diameter and uniform consrtuction, present no problem in maintaining dynamic balance at these high speeds. By way of example, we have a 26-inch single surfacer operating on 120-cycle, about 7,000-rpm., full-load speed. Under such operation, only two knives are used, the other two being set back even with the lip, since the stock to be planed is narrow and in four-foot lengths. The question might be raised, "Why not use 60-cycle current and four knives?" The answer is that the knife travel is doubled under the former condition, and it is the speed or travel of the knife through the cut that counts. Another point in favor of high frequency is that the feed power is less; as we say, the planer feeds more easily. A sharper knife can be used and production increased, in some cases 50 percent. Also, the motor power goes up in the same arithmetical ratio as the speed of the head.

In the summer of 1927, tests were made over a period of six weeks with two 36 inch wide single planers, alike in detail except that one had a four-knife, conventional head and the other a four-knife, spiral head. That is, the knives were similar, but in one machine they were set in straight, while in the other they were held on a one-quarter or 90° twist. The straight knife head was operated on 90-cycle current, 5200 rpm. cutterhead speed, the spiral knife head on 60-cycle current, 3450 rpm. cutterhead speed. The knives were trued, or jointed, ground at 35° bevel to the faintest silver line, and whetted. The cutting angle of the knives in both heads was 25°. The rate of feed was 37½ feet per minute on the spiral head planer, and 55 feet per minute on the straight knife head planer. The knife cuts were approximately 32 per inch in both cases. Glued-up panels of maple, gum, and poplar were planed at different times. The work was held on both machines to a tolerance of 0.0015 inch. There was no apparent difference in the smoothness of the planing. The cost of the spiral cutterheads, the difficulty of locking the knives, and the skill required to grind them in the machine combined to make them impractical, and few, if any, are in use today.

In the building of cabinet, or finishing, precision surfacers, one must be ever mindful of the great and ever-increasing variety of wood and wood compositions to be surfaced. Soft balsa wood, that requires the lower roll to be set 0.015 inch above the center bed or platen, and extremely hard lignum-vitae, that requires almost a zero setting, can be cited as extreme examples of this variety. In practice, most finishing planer lower rolls are carried at a medium roll setting of about 0.005 inches for all kinds of work; but to be more exact, the lower bed rolls should be re-adjusted for the different materials to be planed.

To make this procedure practical, the quick-setting simultaneous lower roll adjuster was developed. The precision surfacer today has micrometer hand wheel and lever adjusters; it also has built-in precision grinders and jointers, for more easily keeping the knives in good condition and eliminating as much as possible of what we call "the human element."

Since present-day planers have a range of quick-change feeds for the job at hand, it is desirable to have more than one speed for the cutterhead. The precision planer cutterhead should have the conventional 3450 rpm. speed and, by the throw of a switch, a higher speed. A good, practical speed of 4500 to 4800 rpm. will give high production and a smooth finish, leaving the cell structure of the wood in its natural state; furthermore, the material, panels or single pieces, can be held on a production basis to a thickness tolerance of 0.002 inch.

To do precision planing on a production basis, there are other prerequisites. The material should have a moisture content of about six percent. The planing room should be held as closely as possible to a constant temperature of about 70 degrees F. The exhaust system should be efficient—not much less than 3½ inches on a water gauge, to avoid shaving choke or shaving printing. Finally, the material, and particularly glued panels, should be first rough surfaced, since the final precision cut is only about 1/32 inch.

Federal Communications Commission Regulations Governing Electronic Heating

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The installation of large numbers of high capacity induction and dielectric heating apparatus has imposed problems of radio interference with the communications industry. The Federal Communications Commission has reviewed the problems with the induction and dielectric heating industry and has issued a set of regulations covering the operation of this equipment.

This paper gives an interpretation of these rules and regulations as applied to industrial induction and dielectric heating equipment.

Introduction

DURING the past ten years a new electronic industry has grown to major proportions. This industry has been commonly called the electronic heating industry and involves the use of radio-frequency power for the heating of electrically conducting and non-conducting materials. The growth in the use of equipment of this style has resulted in the development of many forms and varieties of high-power radio-frequency oscillators or generators. These generators are built in powers which may run from under 100 watts to 300 kilowatts or more. The use of thousands of radio-frequency generators naturally produces problems of radio interference, since a unit of this type is similar in almost every respect to a high-power radio transmitter.

Induction Heating

Electronic heating may be divided into two classes or distinct phases, namely, induction heating and dielectric heating. Induction heating is the heating of an electrically conducting body by subjecting it to a periodically varying magnetic field, which induces currents in the body. Induction heating is principally used for the heating of metals and a few electrically conducting non-metals, such as carbon.

As stated, induction heating is fundamentally produced by a varying magnetic field. This magnetic field in turn, is produced by a work coil which surrounds, or is close to, the object being heated. This work coil may have several hundred or, in some cases, several thousand amperes of radio-frequency current flowing in it. The voltage developed across the coil terminals may be a few hundred volts or several thousand volts, depending upon the coil impedance and current. Since the coil is generally in an exposed position, it is a potential source of radio-frequency radiation which may cause radio interference. In properly designed equipment, any other radiating source will be shielded within a metal cabinet. Induction heating is generally done at frequencies under 500,000 cycles per second, which is below the frequencies of the radio broadcast band and thus will not interfere with this form of communication unless harmonics are radiated by the equipment.

Dielectric Heating

Dielectric heating is the heating of electrically non-conducting bodies or of materials that are nominally insulators, by subjecting them to a periodically varying electrostatic field which causes dielectric losses within the material, which losses appear as heat. This method produces heat uniformly throughout the material and thus offers definite advantages over conventional oven practice, which requires the flow of heat into the work or material by thermal conduction.

Dielectric heating is used industrially for preheating plastics prior to moulding, curing the glue in wood-gluing operations, drying various materials, such as wood, baking foundry cores and other applications where fast uniform heating of a thick material is required.

Radio-frequency radiation from dielectric-heating equipment may be serious, since the frequencies usually used range from 1,000,000 to 200,000,000 cycles per second or more, which is in the same frequency range as many of the radio communication services. The fundamental heating set-up usually consists of electrodes on which a high radio-frequency voltage is applied. This voltage may be as high as 15 kv. The fact that high voltages are used at megacycle frequencies is conducive to appreciable radiation. Therefore particular emphasis must be placed upon the shielding of dielectric-heating equipment as compared to the requirements for induction-heating equipment.

Radio Interference

Electronic-heating equipment is fundamentally a radio-frequency oscillator of the vacuum-tube or spark-gap type, the power of which is utilized to produce heat within various types of materials, rather than being intentionally fed, as in a radio station, to a radiating system called an antenna. However, if the equipment is not properly constructed and shielded, radiation of radio-frequency energy may take place from those component parts which are at high radio-frequency potentials and have appreciable length, thus approaching the requirements of a radio transmitting antenna.

Radio-frequency power may be radiated from any object of finite length carrying an alternating current. Radiation reduces with frequency and, for all practical purposes, can be considered negligible below ten kilocycles per second. The radiation of energy is half in a magnetic field, called the induction field, and half in a dielectric field, both of which may be measured by use of an instrument called a field-strength meter. This instrument, which is much like a radio receiver, will measure the radiation in terms of microvolts per meter. Such instruments are portable and may be moved from spot to spot, making measurements which give a field strength pattern around a given source. Field-strength meters for high frequencies usually use a rod antenna and, at the lower frequencies, use an electrostatically shielded loop antenna.

Radio-frequency radiation is absolutely essential to the functioning of the radio-communications industry. However, in the electronic-heating industry such is not the case. The industry's fundamental purpose is to supply heat energy, and radiation of a radio-frequency nature is not required beyond the confines of the actual equipment. Therefore, if the electronic-heating equipment produce a radiation which may seriously interfere with the communication services, it is justifiable that the communication services should attempt to have regulations established to govern this non-essential radiation. However, these regulations should not be more strict than is necessary to prevent actual interference with the communication services, otherwise the electronic-heating industry becomes excessively burdened and restrained in development.

Assignment of Frequencies

As a result of the above conditions, the Federal Communications Commisison started action in 1944 to set up regulations by which radio interference from induction and dielectric heating equipment could be controlled. Hearings were held in Washington and it was finally decided that the induction and dielectric-heating industries should be allocated several frequency bands of their own, so that radiation could occur without causing interference. The intention of this decision was that, if a piece of equipment was operated at a specific fixed frequency, the radiation from that equipment could not cause any trouble if no radio communication services were in the same frequency band. The frequency bands assigned in 1945, together with the band widths, are as follows:

13.66 megacycles plus or minus 0.05%
27.32 megacycles plus or minus 0.5%
40.98 megacycles plus or minus 0.05%

No specific allowable radiation levels for equipment operating on unassigned frequencies were given at that time. Furthermore, no allocations were made below 13.66 megacycles and, since induction-heating equipment generally operates well below this frequency, it is apparent that no provisions were made for this type of equipment.

In dielectric-heating work, the load or piece of work which is being heated usually changes its electrical characteristics as it is heated. For example, in dielectrically setting glue, water is evaporated and the glue is polymerized by the heat. Both the evaporation of the water and the polymerization cause a considerable change in the dielectric constant and power factor of the material. The fact that these changes occur in the work makes it essential that the radio-frequency generator should be capable of supplying energy to this varying load. If the generator is of a fixed-frequency type, such as would be required to stay within the Federal Communications Commission frequency allocations as given above, it would have to be arranged with special load-following equipment so that it could feed power satisfactorily to a varying load. This is usually not easy to accomplish and, in many cases, adds considerably to the cost of the equipment. Therefore, the use of fixed-frequency equipment with a varying load, such as is usually encountered, is generally not a satisfactory solution.

With a changing load, the simplest form of radio-frequency generator is one in which the change in the electrical characteristics of the load cause the generator to change its frequency of operation. Thus, the equipment does not require any special frequency-stabilizing or load-following devices. However, as can be realized, with the usual frequency shift it would not be possible to stay within the assigned frequency bands. Naturally, this would result in a potential source of interference. The alternative in this case is to shield the equipment, so that its radiation is at a minimum.

Very extensive shielding can be installed on most pieces of equipment which would reduce the radiation to a practically negligible value. However, in a large majority of cases, a reasonable amount of radiation is permissible, since the radiation decreases approximately as an inverse square law with distance. By allowing a reasonable amount of radiation, the shielding can be of a simpler and less expensive nature.

Regulations

In order to determine an acceptable, reasonable amount of allowable radiation, the American Institute of Electrical Engineers collected information on the radiation from such equipment. As a result of this data and cooperative meetings with the Federal Communications Commission, a value of ten microvolts per meter at one mile was settled upon for industrial-induction and dielectric-heating equipment. In addition, a slight change was made in the previously assigned frequency bands. The present assigned bands are:

13.66 megacycles plus or minus 7.5 kc
27.32 megacycles plus or minus 160 kc
40.98 megacycles plus or minus 20 kc

This information is contained in Public Notice No. 7722 of the Federal Communications Commission, which states that industrial-induction and dielectric-heating equipment may be operated within any of the above assigned frequency bands with an unlimited amount of radiation from the equipment.

If it is desired to operate industrial-induction and dielectric-heating equipment outside of the assigned frequency bands, then a maximum radiation of ten microvolts per meter at one mile is permissible.

In order to make sure that the equipment satisfied either of the above conditions, it was required that the equipment be certified by a competent engineer or manufacturer. In the case of operation within the assigned frequency bands, the engineer is required to make measurements on the frequency stability of the equipment under operating conditions. A certificate is then to be posted in the room in which the equipment is situated, stating that the equipment may be reasonably expected to meet the requirements on frequency stability for a period of at least three years. The certificate should describe the equipment and conditions of operation, and briefly describe the tests and the results of the tests on the equipment.

In the case where the equipment is operated outside of an assigned frequency band, tests are to be made to determine the amount of radiated field from the equipment. An approved type of field-intensity meter is to be used. Measurements are to be made at intervals of not more than 20 degrees in azimuthal direction around the equipment and at distances not exceeding 1,000 feet from the equipment.

Measurements should then be made along the radial showing the maximum field intensity, in order to determine the radiation at one mile. Special conisderations must be given to cases where there is evidence of radiation from power lines. A certificate is to be posted in the room in which the equipment is situated, stating that the equipment may reasonably be expected to meet the requirements of the maximum radiation stipulation for a period of at least three years. The certificate should describe the equipment and conditions of operation, and include a brief statement of the tests upon which the certification is based and the results of the tests.

No renewal of the above certificates is required, unless requested specifically by the Federal Communications Commission.

In cases where actual radio interference is caused by industrial-induction or dielectric-heating equipment, even though the equipment may be operated within the rules, steps are to be taken to remedy such interference. The fact that the equipment is operating within the rules, does not, in any way, relieve the owner of the equipment from the responsibility of eliminating actual cases of interference.

These rules were to go into effect on equipment manufactured after June 15, 1947. However, due to the lack of field-intensity measuring equipment, the owners and manufacturers were permitted to certify tentatively equipment manufactured after June 15 and up until December 31, 1947. This tentative certification was to indicate that some preliminary tests had been made which gave an indication that the equipment probably would be satisfactory. After December 31, 1947, all equipment was required to have a final certification.

As stated above, these rules and regulations apply to equipment manufactured after June 15, 1947. They do not apply to existing equipment for a period of five years from July 1, 1947. However, if any equipment manufactured prior to July 1, 1947, causes radio interference, steps must be taken to eliminate the interference.

An order has recently been issued by the Federal Communications Commission making a slight change in the frequency allocations. The new frequency changes, which are to be fully in effect by June 30, 1952, are as follows:

13.560 megacycles plus or minus 6.78 kc
27.120 megacycles plus or minus 160 kc
40.680 megacycles plus or minus 20 kc

There is the possibility that the Federal Communications Commission will make an additional allocation at a frequency near 6 megacycles. This frequency would be of particular interest to the wood industry, since its members often use loads that will operate satisfactorily only at a low frequency.

The existence of these regulations should not hinder the development of the use of electronic heating since, in almost all cases, shielding can be installed which will prevent radio interference. In many cases, this shielding is no more than the usual enclosure or cover over the electrodes which is necessary to protect the operating personnel under normal conditions. Specific data and information on shielding are available from manufacturers of such equipment. In many cases, the manufacturers supply detailed booklets on the subject as part of the certification data.

Basic Tests For Plywood

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A new test for determining the strength of bond of plywood is described in which the glued area between two notches is subjected to torsion shear by a load applied by hand, and bonding strength is measured by the percentage of wood failure.

It is shown that stiffness and puncture resistance are the most important physical properties desired in structural plywood.

An apparatus is described which measures glue bond, stiffness and puncture resistance of plywood.

MODERN plywood is used by designers either for its esthetic qualities or for its unique structural properties. For furniture, the primary consideration is the grain or figure and color of the veneer used, whereas for structural purposes, such as sub-flooring, fancy veneers have no meaning. For the latter use, plywood must not bend noticeably when walked upon, and it must not delaminate.

The present discussion is concerned with means for measuring the value of a piece of plywood for uses where its strength and stiffness are more important than its esthetic appeal. Strength and stiffness are properties that can be measured. We are therefore concerned here with tests which will determine the suitability of plywood of a particular thickness, species and construction for specific uses where its strength properties are important.

Strength of Bond

First and foremost, every user of plywood wants to be assured that the product he is using will not separate into its component layers after installation. The bond holding the veneers together must be permanent and no atmospheric or moisture conditions to which the product may be exposed may materially weaken the adhesive. This does not mean, however, that the most waterproof adhesive must always be used. That would be economically unsound for many uses of plywood. It means simply that when the bond is stressed, whether due to expansion of the veneers by wetting or by shrinkage due to heat and low humidity, the bond must not fail.

When the problem of testing the glue bond of plywood intended for aircraft was submitted to the U. S. Forest Products Laboratory during World War I, a machine used for testing briquettes of cement in tension was selected for testing the strength of bond. It was equipped with special jaws and a test specimen was prepared by notching opposite faces at two places an inch apart, so that upon pulling the ends of the specimen, the bond between the plies was subjected to a form of peeling action, which was partly shear and partly tensile in nature, and the load at failure could be measured. The width of the specimen and the spacing of the notches was standardized so that the area in shear was one square inch in size. In addition to testing air-dry specimens, other specimens soaked in water, and eventually also specimens boiled in water, were included in evaluating the quality of the glue bond. As the center ply of most plywood for aircraft uses was made of low-density woods, hence of woods having relatively low internal strength, a good adhesive would cause the center ply to fail in the wood because the strength of the adhesive exceeded the tensile strength of the wood across the grain. The load at failure was recorded and the approximate percentage of the area of the core veneer that failed in the wood was noted for each specimen tested. Specifications were set up, stating the loads the specimen must sustain under air-dry and soaked conditions.

It is of course obvious that, in addition to variations in moisture, many other factors affect the values obtained in the plywood glue-shear test, such as density of the veneers bonded,

number of plies, and thickness of face veneers. As the glue-shear test for plywood became more widely used, the percentage of wood failure obtained took on more importance until some makers of plywood began to see in the wood failure itself the major criterion of the merit of the glue bond. Assuming that under test the wood fails over most of the area between the notches and that this is true under all moisture conditions, it can be maintained that much greater strength of glue bond is not necessary and that in service such a bond would hold up under all conditions. Observations of failures of the glue bond of plywood under service conditions indicate that when the bond gives way the break is practically always in the adhesive itself, in other words, the break is clean and almost no failure in the wood ever takes place. It is, of course, true that plywood made of certain coniferous woods and exposed to the weather tends to shell or flake, but this is due to weakness in the annular rings of the tree growth and not due to weakness in the adhesive. In the opinion of the author, when most of the area of a plywood test specimen subjected to shear fails in the wood, the actual load under which failure takes place may be ignored and reliance may be placed entirely on the percentage of wood failure obtained. If, on the other hand, most of the area shows failure at the adhesive and not in the wood, such bonding is unsatisfactory.

Other tests for strength of bond can be used, as for example the so-called ten-cycle test, in which the test specimen is soaked in water at room temperature for four hours followed by drying for a period of 20 hours, and this cycle is repeated ten times. Observations are then made of indications of delamination along the edges. This test is of course only applicable for testing adhesives of the water-resistant type. The shear test is applicable to adhesives of all kinds and can be used on boiled specimens as well as on those that are dry.

If the percentage of wood failure obtained in a plywood shear test specimen is a more reliable measure of the strength of the bond than the load under which failure takes place, then methods of testing the bonding strength can be devised which do not involve the measurement of forces. Such a test is the torsion shear test illusdiagrammatically in Figure 1. This test requires no further apparatus than a block containing a slot into which the notched test specimen can be placed and held while a force is applied by hand at one end of the specimen

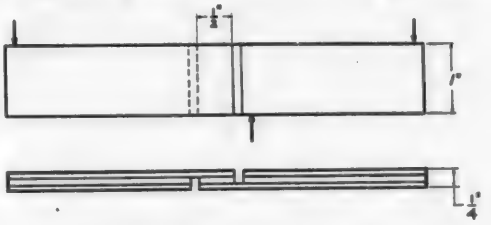


Fig. 1.—Torsion shear test specimen, showing position of forces set up when the specimen is loaded by hand as a cantilever beam.

to subject the glue bond to rotary shear. The test can be made in a few seconds and, besides eliminating costly equipment, it has the further advantage that a number of notches can be cut in one sample strip of plywood to obtain an average result. Due to the simplicity of the test and the speed with which it can be made, we propose its use for control testing in the manufacture of plywood.

Consideration has been given to the spacing of the notches of the torsion shear specimen. As failure sometimes takes place in tension of the face veneer if the notches are one inch apart and the face veneers are thin, a spacing of ½ inch was selected. Tests have been made to determine the correlation between the percentage of wood failure obtained in the torsion shear tests using ½ inch spacing of the notches and the results obtained with the conventional tension shear test using a one-inch notch spacing. The results of both types of tests made on the same specimens are given in Table 1. This table shows that on the whole, there is good correlation between the two and that the torsion shear test may be used for determining the quality of the glue bond just as well as the tension shear test.

By bolting two parallel steel blocks an inch apart on the frame of the wall-board tester shown in Figure 2, the torsion shear test can be made on this piece of equipment. Figure 2 shows the test specimen in place and the force being applied to the specimen by hand. The only record made is the percentage of wood failure noted in the fracture.

TABLE 1.—PERCENT WOOD FAILURE OBTAINED WITH THE TENSION SHEAR TEST COMPARED WITH VALUES OBTAINED WITH THE TORSION SHEAR TEST

(Courtesy Harbor Plywood Corporation)

	Tension Shear Test (10 Specimens Each Test) Percent Wood Failure		Torsion Shear Test (5 Specimens Each Test) Percent Wood Failure	
Test No.	Dry	Boiling Cycle	Dry	Boiling Cycle
1	95	92	92	85
2	75	82	66	65
3	95	93	84	93
4	85	93	67	72
5	90	90	83	98
6	96	93	92	86
7	100	81	89	98
8	86	75	74	50
9	96	91	85	90
10	85	91	100	98
11	80	87	95	72
12	93	93	94	98
13	91	89	85	95
14	78	95	78	95
15	95	86	85	96
16	95	88	88	66
17	98	98	99	98
18	95	72	95	85
Average Percent Wood Failure	91	87	86	85

Plywood Strength Tests

When the engineer uses the term "strength" in connection with building materials, he may refer to tensile strength, compressive strength, shear strength or modulus of rupture. All of these concepts express the maximum resistance of a material to external forces of various kinds. If he knows the strength of the material he uses and the kind and magnitude of the forces to which it is subjected, the engineer can determine the cross-sectional dimensions of the part he is designing. For example, in designing a plywood wing for an airplane, he would have to know the magnitude, direction and nature of the greatest forces to which the airplane would be subjected in service and, knowing the strength properties of the plywood under consideration, he could then determine the thickness of the plywood that should be used, the ratio of the core to the face veneer thickness and the direction of the grain of the respective plies. Unfortunately, the forces to which a structural member made of plywood are subjected in service are rarely known, so that the computation of the thickness to use is rarely possible. Even in the design of airplane parts, assumptions must be made in regard to magnitude and direction of the forces involved. If the assumptions are correct and adequate factors of safety are used, then reasonably reliable computations can be made. The unreliability lies in the starting point, in the assumptions.

If an architect wants to compute the thickness of plywood to use for sub-flooring so that it will not break in service, he has to know two things, (a) modulus of rupture of the plywood and (b) the load it must support. Figures for the former are available, but in postulating the forces or loads the sub-flooring must sustain, the architect must make sweeping assumptions the accuracy of which would be highly questionable. A careful search for uses of plywood in which the forces to which it is subjected in practice are accurately known shows that such uses are practically non-existant. In other words, elaborate tables of tensile, compressive or bending strength of plywood are practically useless, because the forces to which the plywood is subjected in service are never known with any reasonable degree of accuracy. It is true that such tables yield some information regarding the relative strength of plywood made of different species, but substantially the same information can be obtained from the various tables of strength of wood available in most handbooks.

But all plywood used structurally is subjected to forces of some kind and magnitude. Is it not possible then to make tests of some kind that would throw light on the suitability of plywood of a certain construction and thickness for a particular use? This, in the opinion of

Fig. 2.—Torsion Shear Test for Plywood.

the author, is possible if a basis of comparison exists. In other words, if plywood or any other material of known construction has been found satisfactory in practice for a particular use, then it becomes possible to make comparative tests which would determine whether plywood of another construction is satisfactory for the same use. It is only necessary to decide which strength properties are of major importance and then to test the new against the old and make the comparison. To revert to sub-flooring, it will be found that the thickness of the plywood to use is not determined by the breaking load, but by its stiffness. A floor which will support a piano may not be thick enough, because it may be too "springy" for a proper feeling of security when a person walks on it. Comparisons must be made with lumber sub-flooring known by experience to be satisfactory in this respect. Some allowance must also be made for the fact that a much greater width of flooring comes into play when plywood is used.

In the case of wall paneling, two strength properties are primarily wanted, (a) the wall must not be easily ruptured by a blow and (b) it must be stiff, so that when a person pushes against it he gets an impression of rigidity which in the layman's mind is the same as strength. For this the plywood must be tested for puncture resistance and stiffness and if found superior to other materials more or less satisfactory, then this fact should be made known to the purchaser.

A careful consideration of many uses for structural plywood will show that the load at which a piece of plywood will fail when it is tested in cross-bending as a simple beam is not nearly as important as the ability of the plywood to resist puncture from a severe blow. It will also show that stiffness, or the ratio of load to deflection within the elastic limit, is more important than bending strength.

(a) Puncture Tester

Having long been convinced of the importance of puncture resistance in any wallboard, the puncture tester shown in Figure 3, was developed in the Elmendorf laboratory. The design of the plunger, its weight, and the shape of the conical point have been standardized and many tests have been made with this

Fig. 3.—Elmendorf Wallboard Tester As Used for Determining the Puncture Resistance of Plywood.

apparatus in the course of its use in the laboratory. Details of the plunger design will be found in Figure 4. The plunger rod and the conical spear together weigh ten pounds.

In using the wallboard tester for determining puncture resistance, the panel to be tested is clamped between the restraining frame and the base as shown in Figure 3. The panel is 12 by 12 in. in size. The pointer at "P" is then set for Zero, after which the spear is raised ½ inch and allowed to drop on to the

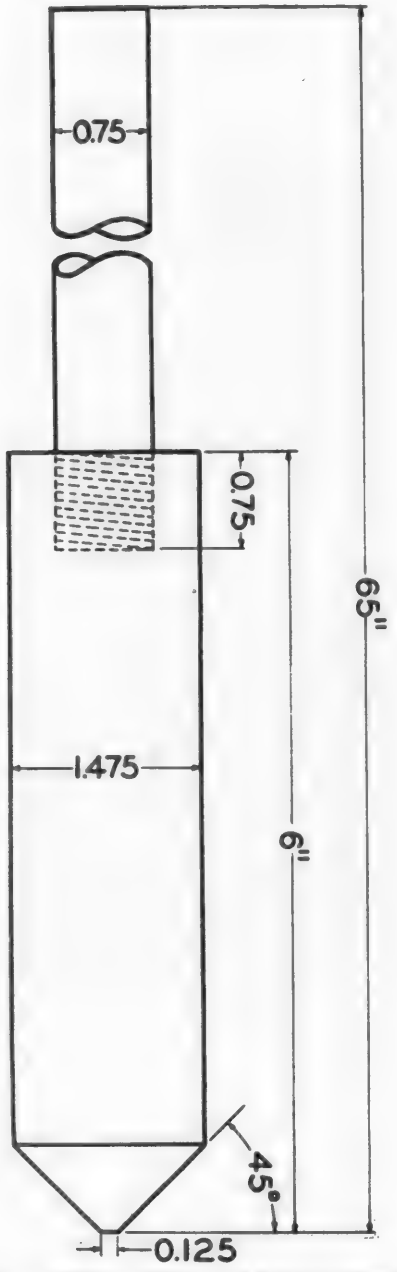


Fig. 4.—Detail of Plunger and Spear of Elmendorf Wallboard Tester.

panel. It is then raised to one inch and allowed to drop again, and then raised successively higher by increments of ½ inch until failure

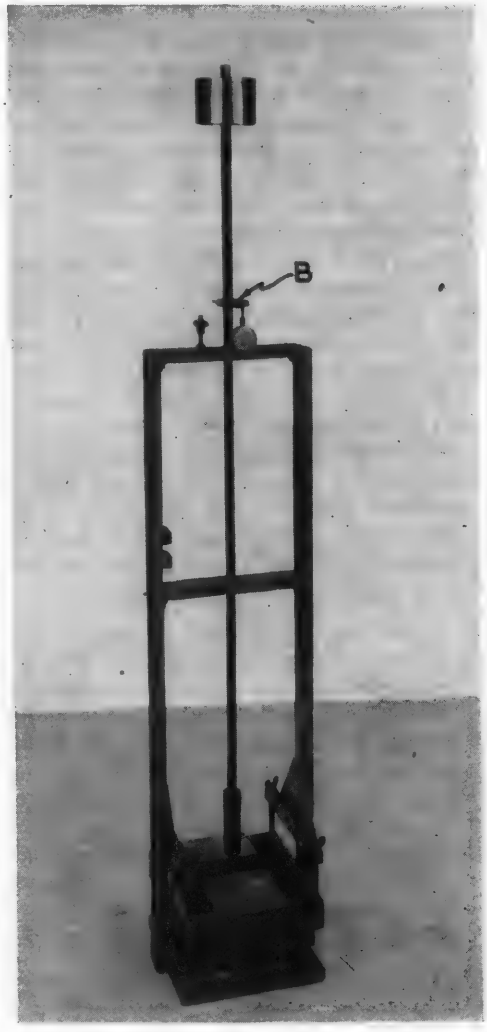


Fig. 5.—Elmendorf Wallboard Tester As Used for Determining the Stiffness of Plywood.

takes place, record being made of the height of drop at final failure, when the plunger breaks through. Two comparisons can then be made, by comparing the maximum height of drop, and the total sum of the heights through which the plunger dropped to produce failure. No absolute value may be placed upon the data so obtained, but they are valuable in comparing the relative resistances to puncture of various types and thicknesses of plywood.

Table 2 lists the results of the puncture test on a few typical wallboards used on a substan-

TABLE 2.—PUNCTURE-RESISTANCE OF VARIOUS WALLBOARDS

Material Tested	Height of Drop at Failure, in Inches
¼" 3-ply Douglas-fir plywood	12.0
Metal-faced K-Veneer	11.5
Exterior K-Veneer	10.5
¼" 3-ply Douglas-fir plywood	8.0
K-Veneer underlayment	6.5
½" Insulation Board	5.5
Interior K-Veneer	4.5
½" Gypsum Board	4.5
⅛" Hardboard	4.0
½" Insulation Board	3.5
⅝" Gypsum Board	3.0

tial scale in industry. The great superiority of plywood in puncture resistance probably accounts more than anything else for the extensive use of plywood.

(b) Testing Stiffness

The same apparatus used for testing puncture can also be used for testing the stiffness of various types of boards. The specimen to be tested is 6 by 12 in. in size. It is placed on top of the frame at the base and the plunger is allowed to rest upon a bar placed upon the middle of the specimen, as shown in Figure 5. An arm (b) is clamped on to the plunger rod and a Zero reading is taken on the dial. A five- or ten-pound weight is then placed on top of the plunger and the dial is read again. This may be repeated for several additional loads so that a curve can be plotted between load and deflection. Figure 6 shows the load-deflection curves so obtained for a number of materials. Comparisons can also be made of the stiffness of plywood when the face veneers extend across the supports with the results when the face veneers are parallel to the supports. The stiffness is measured by the slope of the load-deflection curve within the elastic limit. Numerically it represents the load per 1/10-inch deflection. No absolute value can be placed upon the stiffness figure so determined, but it will be found very useful when com-

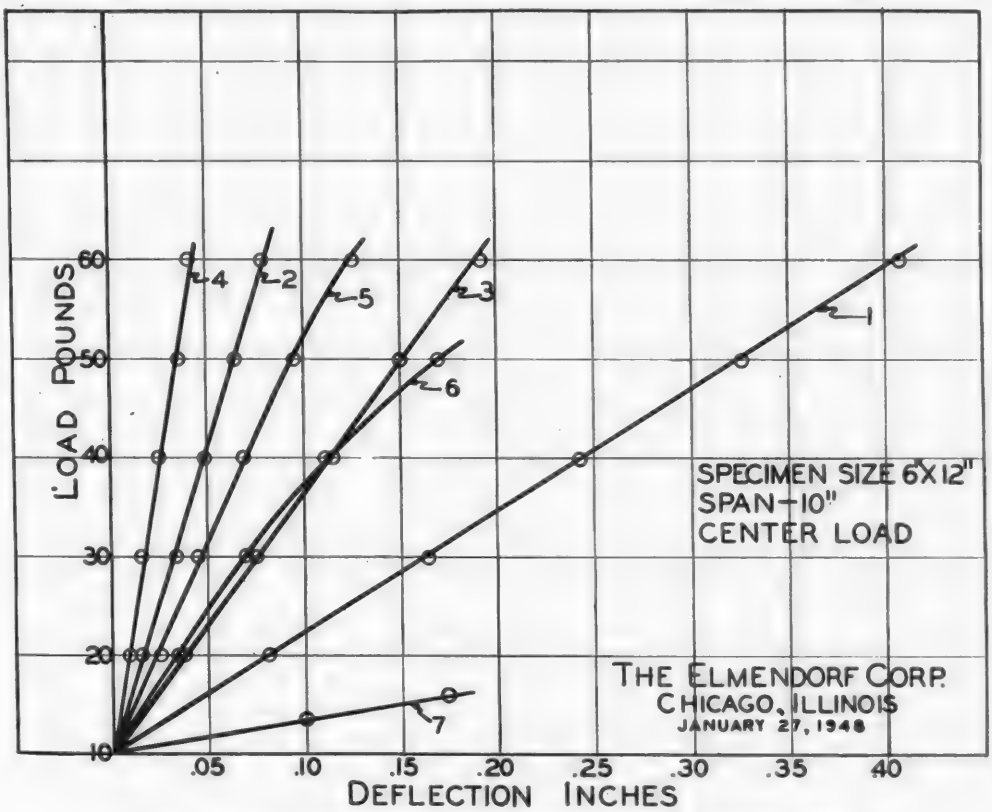


Fig. 6.—Load-Deflection Curves Obtained with Elmendorf Wallboard Tester.

paring plywood of one construction or thickness with another construction or thickness, as well as for comparing plywood with other board-types of materials.

Table 3 lists the stiffness of several materials. The marked superiority of plywood in its stiffness when compared with other extensively used materials probably accounts in a large measure for its extensive use.

TABLE 3.—STIFFNESS OF VARIOUS WALLBOARDS, AS MEASURED BY THE ELMENDORF WALLBOARD TESTER

Specimen Number	Material Tested	Stiffness Lb. Per 1/10" Deflection
1	¼" 3-ply Douglas-fir plywood, tested with grain of face veneers parallel to supports	12.5
2	Same as No. 1, tested with grain of face veneer across supports	62.0
3	⅜" 3-ply Douglas-fir plywood, tested with grain of face veneers parallel to supports	26.5
4	Same as No. 3, tested with grain of face veneer across supports	115.0
5	½" Gypsum Board, tested with machine direction of board across supports	42.0
6	½" Insulation Board, tested with machine direction of board across supports	28.5
7	½" Insulation Board, tested with machine direction of board across supports	3.5

Conclusions

While the torsion shear test described has only recently been developed, it is felt that due to its simplicity it merits consideration for control testing of plywood glue bonding in manufacture.

The stiffness test and the puncture test described in this paper test the two most important physical properties desired in structural plywood. They throw valuable light on the merit of plywood of various constructions for particular uses, and permit comparisons of plywood with other types of boards used in industry where strength and stiffness are important.

FOREST PRODUCTS RESEARCH SOCIETY

Spiral-Veneer Drums and Tubes

E. George Stern

Research Professor and Head, Department of Wood Construction, Director, Wood Research Laboratory, Virginia Polytechnic Institute

The advantages and feasibility of mass production of spiral-veneer pipe are indicated for the manufacture of drums, tubes, and containers for numerous purposes. Mass-production methods, as developed by the Virginia Polytechnic Institute Wood Research Laboratory and independently by other organizations, are described for the continuous production of such spiral-wound pipe. Summary test data are presented on the resistance to internal and external stresses of laminated, cross-laminated, and plywood sections consisting of multiple layers of veneers with grain at specified angles to the principal axis and with various types of splices for both veneers and cross-veneers. Reference is made to the supporting interaction of adjacent veneers with grain and cross-grain at an angle to the direction of load application. Emphasis is given to the lack of test information on the influence of compression-perpendicular-to-grain stresses on simultaneously acting tension-parallel-to-grain stresses in pipes and containers under internal pressure.

THE mass production of plywood drums has been aimed at for more than 75 years, in the desire to provide shipping containers that afford satisfactory protection to the contents from the weather and minimize inconveniences, damage during shipping, and loss in handling. The purpose of this paper is to provide manufacturers, packers, and shippers with information regarding advanced mass-production procedures for tight light-weight plywood drums and tubes built up with a multiple number of layers of spiral-wound wood veneers. The mass production of such drums may make it unnecessary to ship products such as import and export articles, in water-tight holds and to store them under full protection from the elements. To date, numerous items have to be shipped in not fully satisfactory containers that often originate in distant production centers. The mass production of plywood drums, on the other hand, may take place at the origin of the product to be shipped, provided the principal construction material, wood veneer, is available locally. The production procedure described and the test data presented for spiral-wound drums and tubes resulted from investigations performed in the V.P.I. Wood Research Laboratory under the auspices of the V.P.I. Research Foundation, Inc., and under the sponsorship of the Regional Products Research Division of the Commerce Department of the Tennessee Valley Authority, on behalf of the Services of Supply and the Corps of Engineers of the U. S. Army.

Manufacture of Spiral-Veneer Drums and Tubes

Light-weight plywood drums have been in limited use as containers for various purposes. Their mass production, however, awaits introduction of machinery for continuous manufacture. One step toward production of plywood drums at economical speed is the introduction of the procedure for convolute winding of edge-glued veneers over mandrels of round, square, or irregular cross-section, as advanced during World War II (1) for the manufacture of light tubes and containers of high strength. An especially prepared continuous strip of wood veneers of a width equal the length of the container is fed at right angles onto a mandrel, as indicated in Figure 1. The strip consists of edge-glued panels having a length equal to the circumference of the mandrel. The grain may be at right or other angles in successive panels, resulting in cross-grain

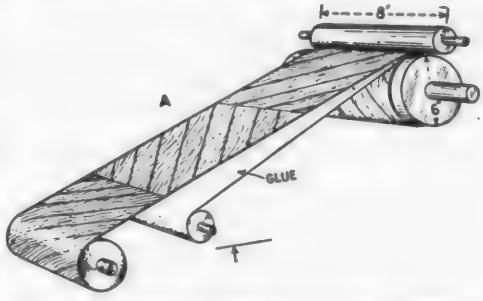


Fig. 1.—Convolute winding of plywood drums.

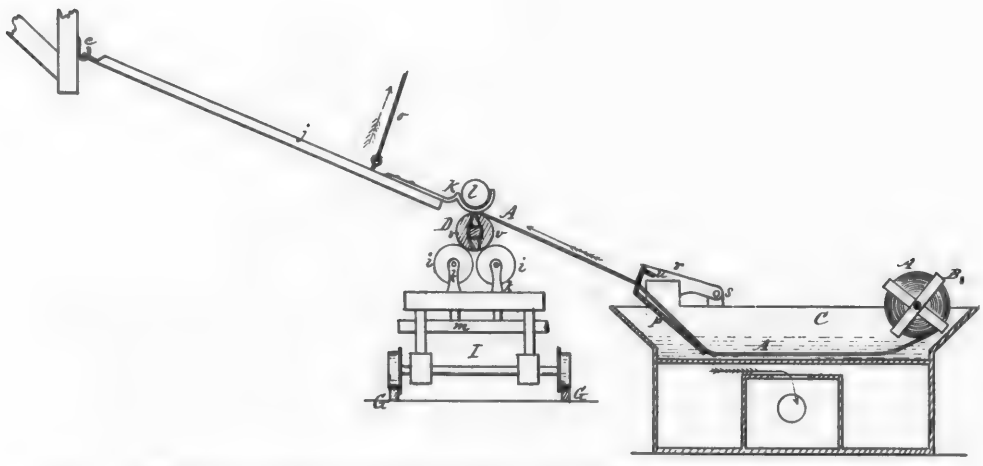


Fig. 2.—Winding mechanism for the manufacture of composition pipes, as patented in 1872.

fiber arrangement. The number of windings, veneer species and thickness are determined by the requirements of the end product. Feeding a continuous dry glue film, such as Tego film, onto the mandrel to act as binder between layers was found to be advantageous, inasmuch as application of liquid glue could be eliminated. The production of drums of different cross-sections is accomplished by winding over round, square or irregularly shaped mandrels of proper size.

For the production of pipe, which can be sawn into containers of desired length, numerous procedures for spiral-winding veneers have been advanced, most of which, however, never got out of the laboratory stage. The earliest description of a spiral veneer-winding machine dates back to 1872[2], as shown in Figure 2. Fundamentally similar is a production set-up independently designed in 1942[3], which takes into account the production technique with available synthetic resin-glues particularly suitable for this purpose, as indicated in Figure 3. During the same year the production of plywood containers from such spiral-wound pipe was again recommended[4] and during the following years several other production methods were advanced for spiral-wound plywood pipe and tubing, thus for the manufacture of plywood drums. One of the patented proposals suggests setting the binder by applying pressure differentials between the inside and outside of the tube during polymerization[5], while most of the other proposals require the use of more conventional means of pressure application.

To provide for production of endless plywood pipe for the continuous manufacture of tubes and drums of any desired length, a one-directional manufacturing procedure was advanced[6] according to which a multiple number of veneers is spiral-wound around a rotating stationary mandrel, as indicated in Figure 4. This procedure has not been put into operation, but is considered feasible and practical.

The two structural materials required are wood veneers and synthetic resin glues. Different species, grades and kinds of veneers may be used for successive veneer layers. Thus, impregnated and compregnated veneers may be employed for any of the layers, if desired, in order to increase the strength of the wall section, to provide for seal against leakage in addition to that of the glue lines, to obtain smooth surfaces, and to attain full decay-resistance. Quick-setting, water-, oil-, gas-, and fungi-resistant synthetic resin glues may be used to allow quick initial setting of the glue at elevated temperatures and to assure its complete polymerization before, during, and immediately upon removal of the pipe from the mandrel. The amount of glue is controlled to eliminate glue and air pockets and, at the same time, to fill any crevices between veneer strips into

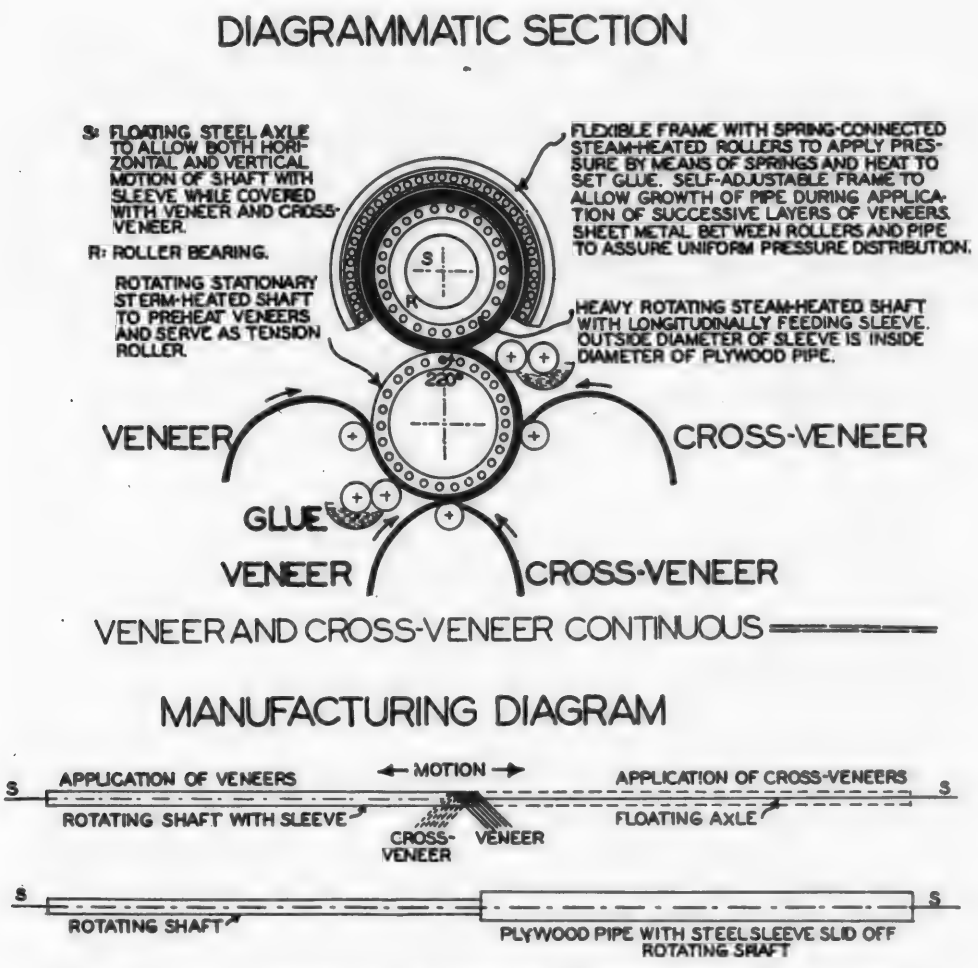

DIAGRAMMATIC SECTION
S: FLOATING STEEL AXLE TO ALLOW BOTH HORIZONTAL AND VERTICAL MOTION OF SHAFT WITH SLEEVE WHILE COVERED WITH VENEER AND CROSS-VENEER.
R: ROLLER BEARING.
ROTATING STATIONARY STEAM-HEATED SHAFT TO PREHEAT VENEERS AND SERVE AS TENSION ROLLER.
FLEXIBLE FRAME WITH SPRING-CONNECTED STEAM-HEATED ROLLERS TO APPLY PRESSURE BY MEANS OF SPRINGS AND HEAT TO SET GLUE. SELF-ADJUSTABLE FRAME TO ALLOW GROWTH OF PIPE DURING APPLICATION OF SUCCESSIVE LAYERS OF VENEERS. SHEET METAL BETWEEN ROLLERS AND PIPE TO ASSURE UNIFORM PRESSURE DISTRIBUTION.
HEAVY ROTATING STEAM-HEATED SHAFT WITH LONGITUDINALLY FEEDING SLEEVE. OUTSIDE DIAMETER OF SLEEVE IS INSIDE DIAMETER OF PLYWOOD PIPE.
S
R
220°
VENEER
CROSS-VENEER
GLUE
VENEER
CROSS-VENEER
VENEER AND CROSS-VENEER CONTINUOUS
MANUFACTURING DIAGRAM
S
APPLICATION OF VENEERS
MOTION
APPLICATION OF CROSS-VENEERS
S
ROTATING SHAFT WITH SLEEVE
CROSS-VENEER
VENEER
FLOATING AXLE
S
S
ROTATING SHAFT
PLYWOOD PIPE WITH STEEL SLEEVE SLID OFF ROTATING SHAFT

Fig. 3.—Winding Mechanism for the Manufacture of Plywood Pipe with Wood Veneers and Synthetic Resin Glues.

which the glue is forced as a result of the pressure applied. Rotary 1/16-inch or thinner strips of uniform widths and standard lengths—possibly cull veneers not acceptable for highly stressed plywood structures because of minor deficiencies and specific-gravity limitations—are glued up to continuous strips from standard lengths by scarf-jointing or by overlapping one-half of one veneer with one-half of the following one, thus manufacturing a strip of double thickness. The prefabricated strip of specified length is wound on a reel from which it is unrolled during pipe production. Automatic replacement of empty reels with full reels and splicing of the strips allow continuous production. The most desirable angle of spiral-winding is predetermined according to the properties required of the wall section. The reels are mounted, at angles corersponding to the direction of the spiral-winding, in cages rotating around the production axis. Since adjacent cages may be rotated in opposite directions, the successive veneer layers may have their fibers in cross-grain direction. Overlapping of the tight edge-abutted joints of successive veneer layers can be ascertained by satisfactory provisions.

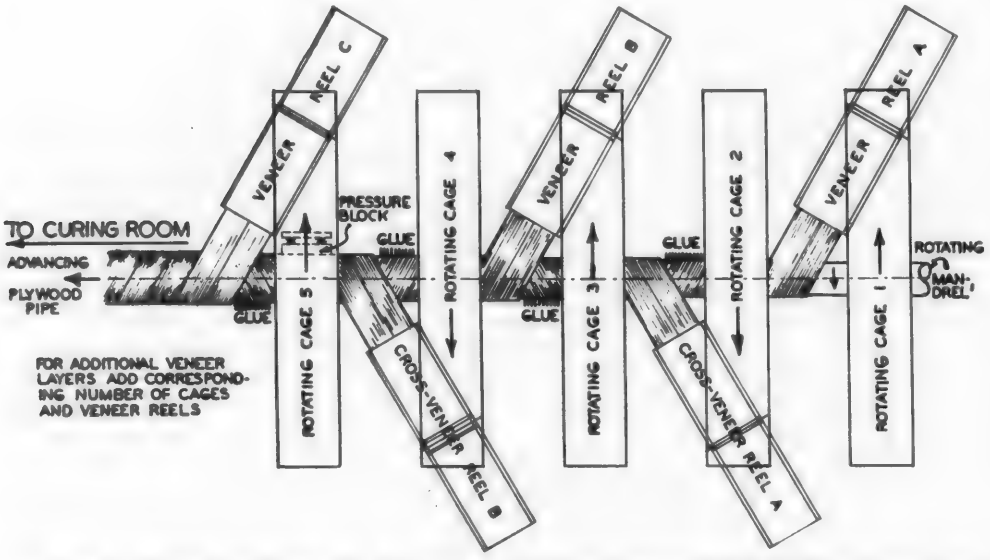


Fig. 4.—Winding mechanism for the endless one-directional mass-production of plywood pipes, tubes, containers and drums of any desired length and diameter, as advanced by the V.P.I. wood research laboratory.

The stationary veneer-winding equipment requires a continuous motion of the spiral-wound plywood pipe in the production direction. This is attained by means of a stationary and rotating mandrel with a multitude of gear-driven rotating spiral rollers, as indicated in Figure 5. Because of the rigidity of the pipe after application of only a few veneer layers, the mandrel does not have to extend further than called for by the rigidity requirements for application of the veneers under tension. The mandrel is designed to cantilever from the feeding end into the direction of production and rotates opposite to the direction of rotation of the first veneer-feeding cage. By rotation of the mandrel and counter-rotation around their own axes of the spiral-surfaced rollers mounted along the surface of the mandrel, the wound and glued-up veneers are forced to advance continuously along the direction of production.

At the start, the veneer strips are stapled to the wooden head fixed to the mandrel in order to be pulled spirally over the mandrel from the reel. The head advances with the pipe, is to be severed from it, and can be reused.

Glue may be sprayed, as indicated in Figure 4, and is applied to the outer face of each veneer strip, except the last one to be wound,

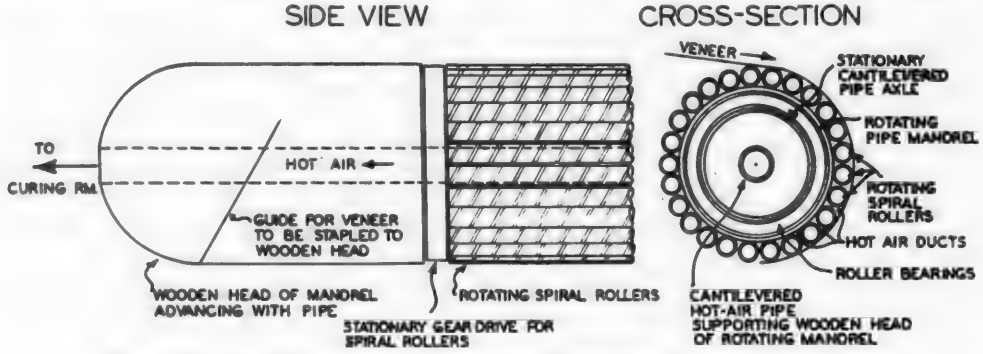


Fig. 5.—Mandrel for the endless one-directional production of plywood pipe of any desired length and diameter.

immediately before the succeeding strip is wound on.

Tension is applied to the strips by the action of brakes on the reels and results in compression between successive layers. Additional pressure is produced by spring-seated pressure blocks mounted on the rotating cage and coming into action immediately upon contact of the layer with the glue-covered surface with the preceding layer. These pressure blocks may also serve as guides for the spiral-wound veneer, and thus guarantee tight edge-abutted contact with the previous adjoining veneer, eliminate air and glue pockets and crevices between veneers, and force glue into any existing crevices. The heat for initial polymerization of the inner glue lines is provided by hot air forced through the mandrel or by means of high-frequency currents, the mandrel acting as one electrode. Setting of the outer glue lines and complete polymerization of all glue can take place as the pipe moves from the mandrel through a high-frequency field, or through a curing chamber in which hot air surrounds the finished pipe, pressure being maintained as a result of the tension applied during winding.

Upon complete polymerization of the glue, sections of desired lengths are cut off the continuous pipe by a traveling saw. Provision is made for the insertion of suitable plywood heads and a tight joint between pipe sections and heads. The pipe diameter is determined by the diameter of the mandrel and by exchange of mandrels, pipes and drums of any desired diameter may be manufactured.

Similar, and in certain aspects identical, details for such a set-up are advanced in a patent disclosure of recent date[7], as indicated in Figure 6. Instead of using the previously described mandrel mechanism to advance the progressively wound pipe, several endless feeder belts are employed to advance tractively the plywood tube from the stationary mandrel, a procedure similar to the one pursued by manufacturers of spiral paper tubing. Provision is also made for wrapping of veneer layers parallel to the pipe axis by means of folding dies.

Design Data for Spiral-Veneer Drums and Tubes

Only limited data are available on the strength of spiral-wound plywood pipe and containers.

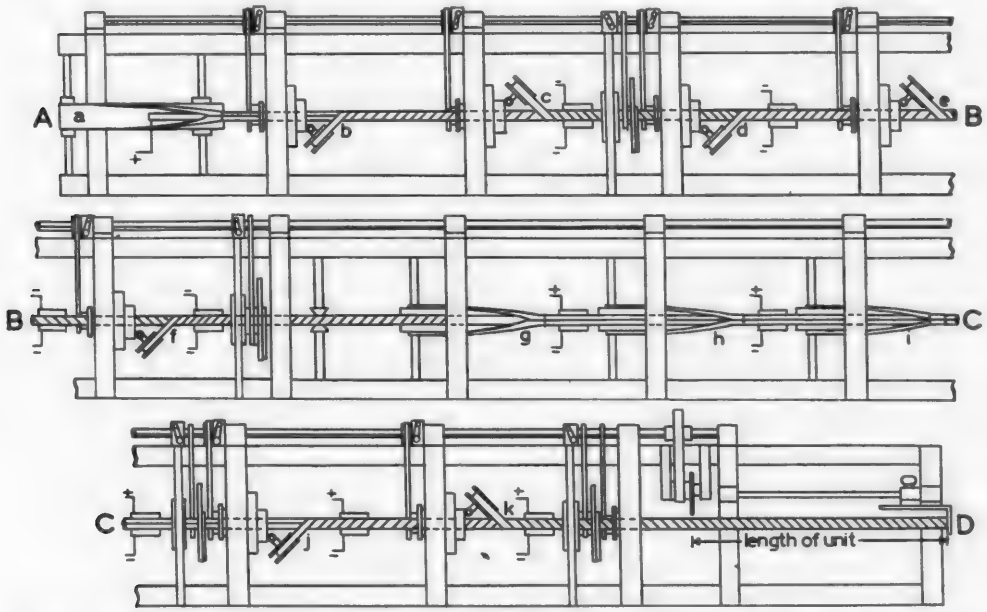
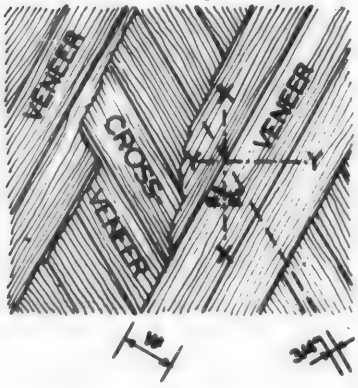
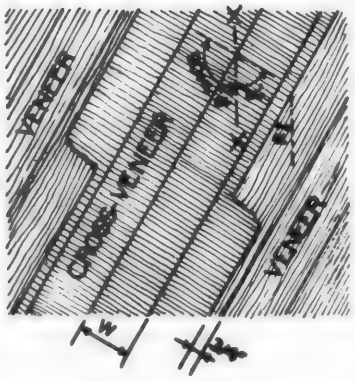


Fig. 6.—Winding mechanism for the endless one-directional mass-production of plywood pipe of any desired length and diameter, as patented in 1946.



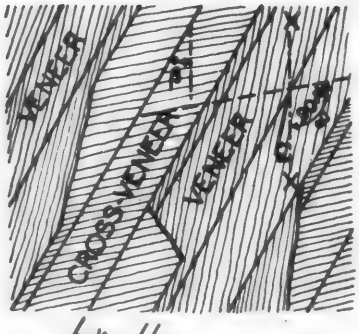
A VENEERS & CROSS-VENEERS AT SAME ANGLE TO PRINCIPAL AXES

TEST ANGLES:		
	0° x 0°	(1)
	15° x 15°	(2)
	30° x 30°	(3),(5)
	45° x 45°	(4)
	60° x 60°	(5),(3)
	75° x 75°	(2)
	90° x 90°	(1)
also:	45° x 75°	(18)



B VENEERS AT 90° TO DISCONTINUOUS CROSS-VENEERS (STRIPS IN DIRECTION OF VENEER)

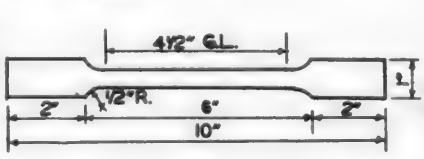
TEST ANGLES:		
	0° x 90°	(6)
	15° x 75°	(7)
	30° x 60°	(8)
	45° x 45°	(9)
	60° x 30°	(8)
	75° x 15°	(7)
	90° x 0°	(6)



E VENEERS & CROSS-VENEERS DISCONTINUOUS AND VENEERS AT 90°+2α TO CROSS-VENEERS

TEST ANGLES: FOR β=45°, α x α':	
0° x 90°	(10)
15° x 105°	(11),(14)*
30° x 120°	(12),(15)*
45° x 45°	(9)
120° x 30°	(15),(12)
105° x 15°	(14),(11)
90° x 0°	(10)
also: 0° & 90°	(13)
also: 45° x 90° x 45°	(17)

TEST SPECIMEN USED:



• VENEER CONTINUOUS *β=135° FOR 14 & 15

Fig. 7.—Three types of cross-laminated construction of 1/32-in. veneer yellow-poplar panels under investigation.

In order to provide data for rational design of pipe, tubes, and drums consisting of multiple layers of interacting veneers with the grain at any specified angle to the principal axis, a study was performed of the influence of the direction of fibers and of various types of splices in the veneers on the tensile strength properties of yellow-poplar cross-laminated wood and plywood.[8] Three types of seven-ply panels of matched 1/32-inch yellow-poplar veneer, as indicated in Figure 7, were tested in tension along the two principal axes with the direction

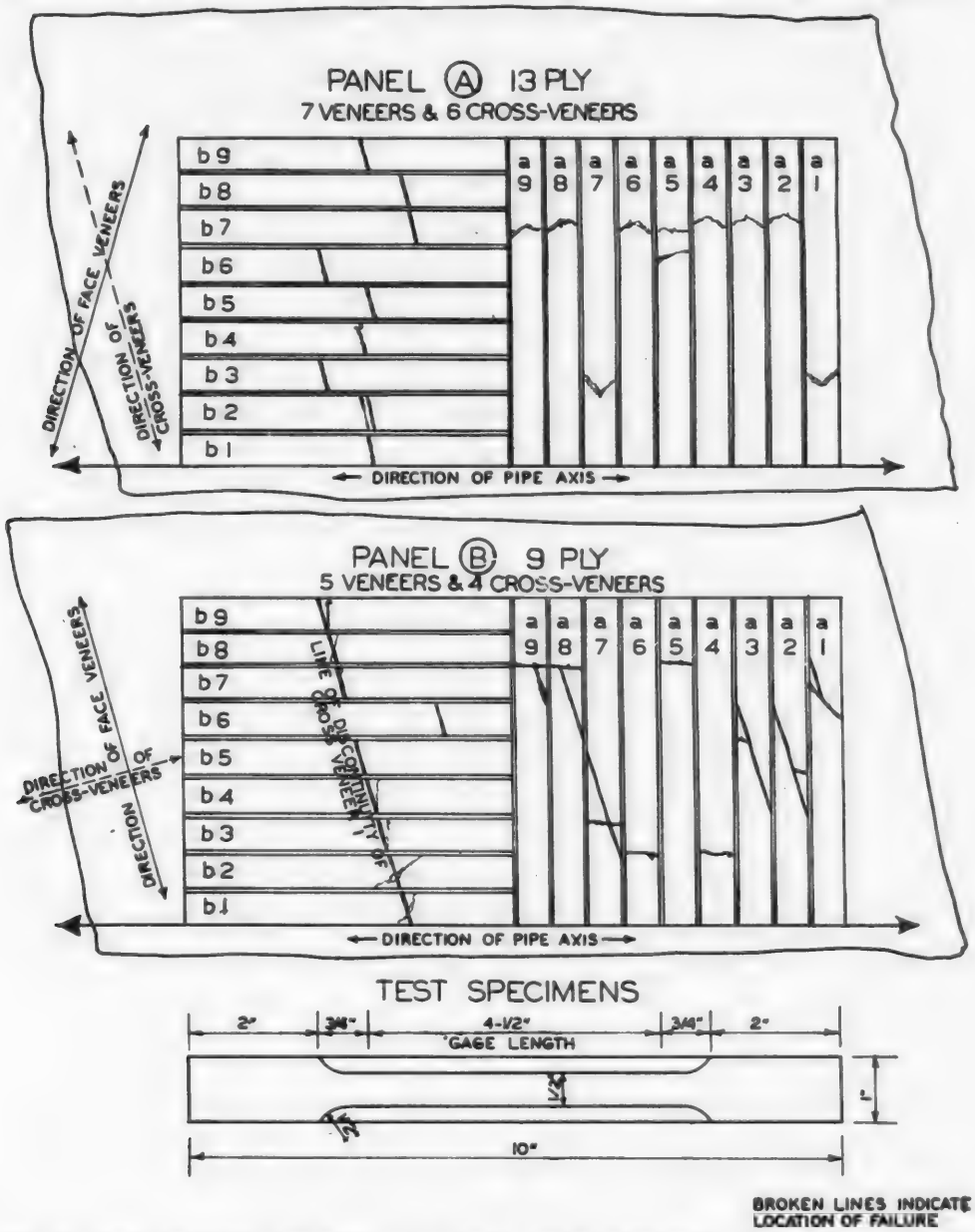


Fig. 8.—Cutting schedule for test specimens for 1/48-in. veneer yellow-poplar panels under investigation.

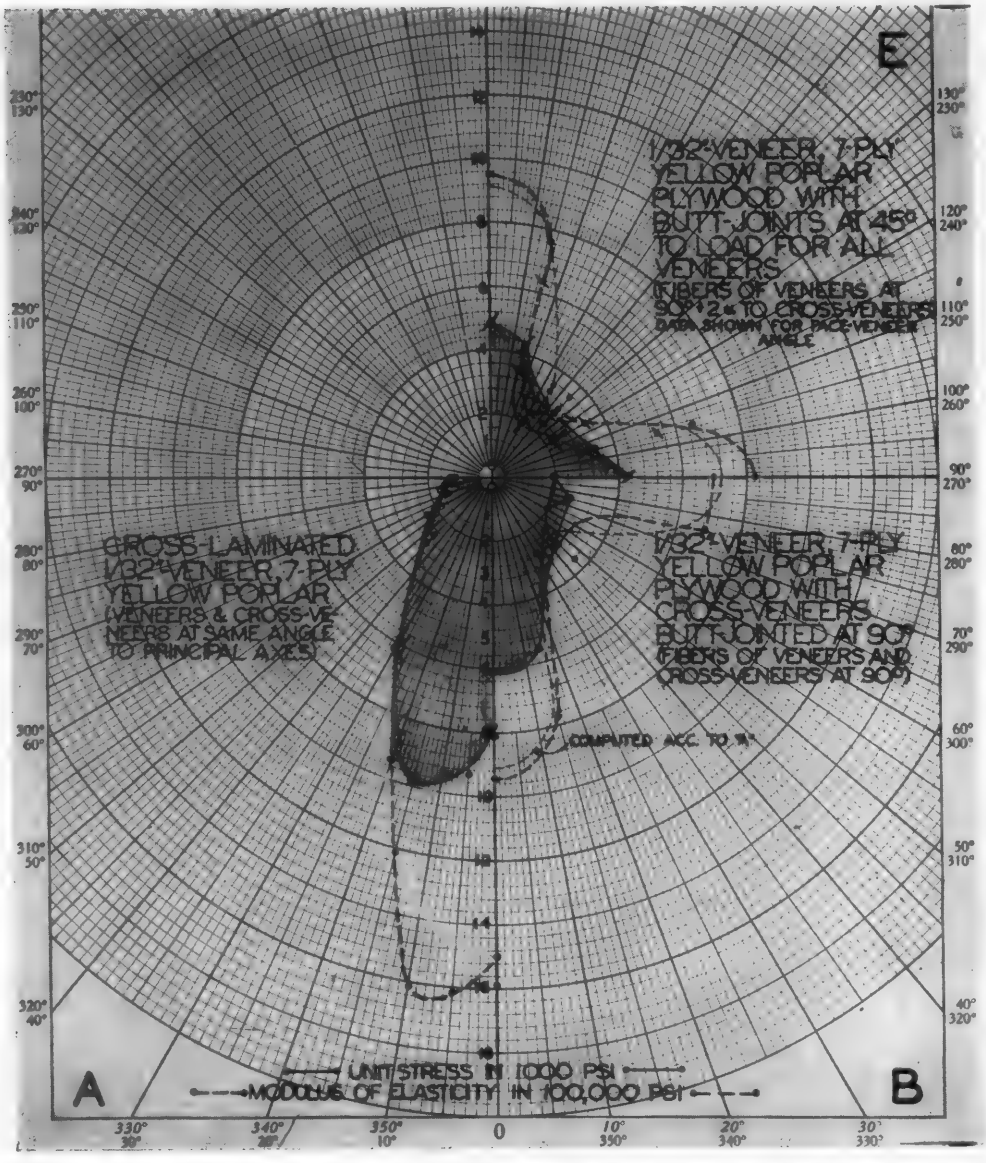

E
1/32"-VENEER, 7-PLY YELLOW POPLAR PLYWOOD WITH BUTT-JOINTS AT 45° TO LOAD FOR ALL VENEERS
(FIBERS OF VENEERS AT 90° TO CROSS-VENEERS; DATA SHOWN FOR FACE-VENEER ANGLE
CROSS-LAMINATED 1/32"-VENEER, 7-PLY YELLOW POPLAR (VENEERS & CROSS-VENEERS AT SAME ANGLE TO PRINCIPAL AXES)
1/32"-VENEER, 7-PLY YELLOW POPLAR PLYWOOD WITH CROSS-VENEERS BUTT-JOINTED AT 90° (FIBERS OF VENEERS AND CROSS-VENEERS AT 90°)
COMPUTED ACC. TO
UNIT STRESS IN 1000 PSI
MODULUS OF ELASTICITY IN 100,000 PSI
A
B
0

Fig. 9. —Influence of direction of fibers and splices of veneers on strength properties of 7-ply 1/32-in. veneer yellow-poplar panels.

of the veneer strips and/or grain of veneers at 0, 5, 10, 15, 20, 30, 45, 60, 70, 75, 80, 85 or 90 degrees to the direction of applied load. Average data for proportional limit and modulus of elasticity, as influenced by direction of fibers and discontinuity of the grain as a result of butt splicing, are summarized in Figures 9 and 10, for panels with an average moisture content of 18 percent, based on oven-dry weight, and with average specific gravity of 0.58, based on oven-dry weight and volume. Additional tensile and compressive strength

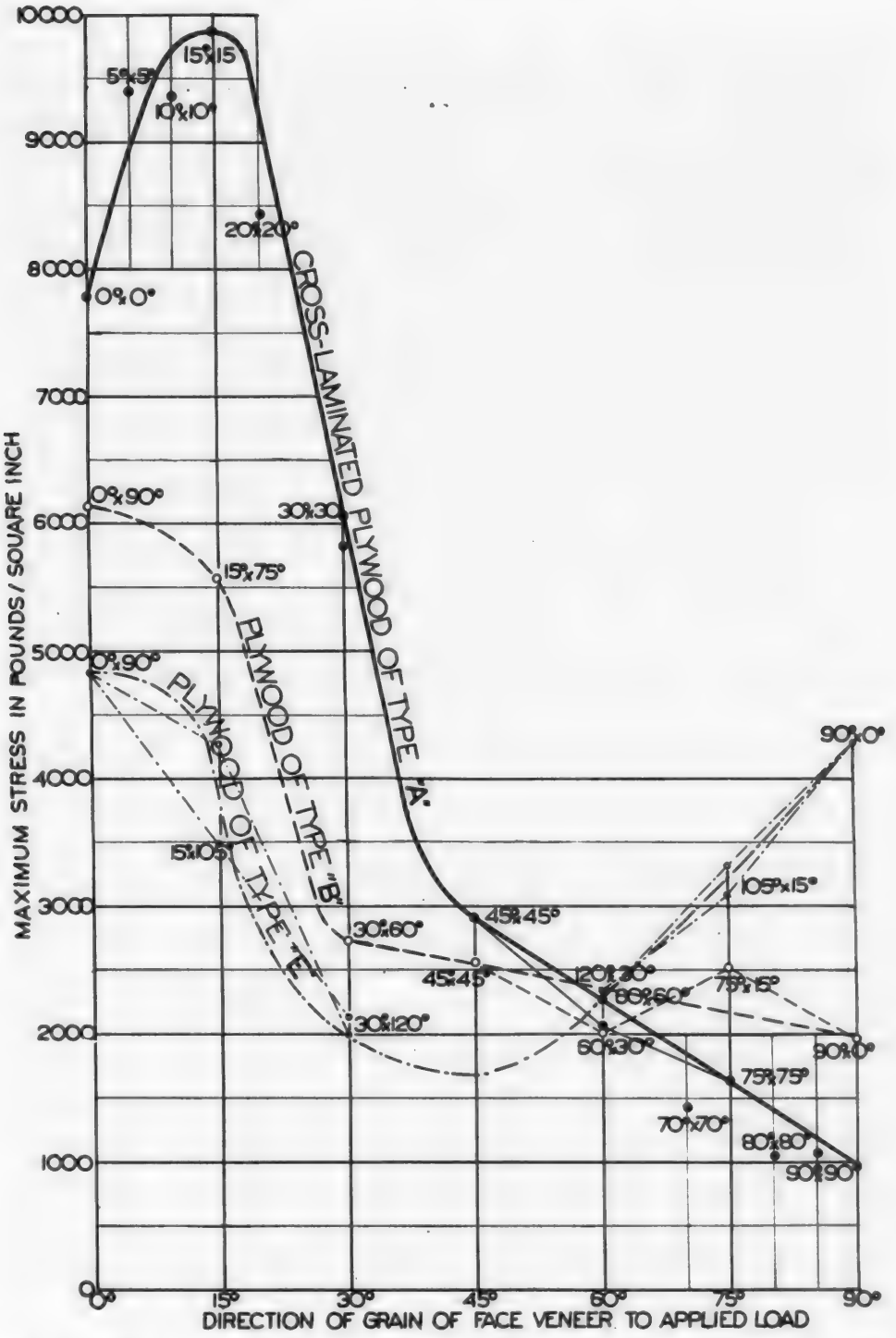


Fig. 10.—Influence of direction of fibers and splices of veneers on ultimate tensile strength of 7-ply 1/32-in. veneer yellow-poplar panels.

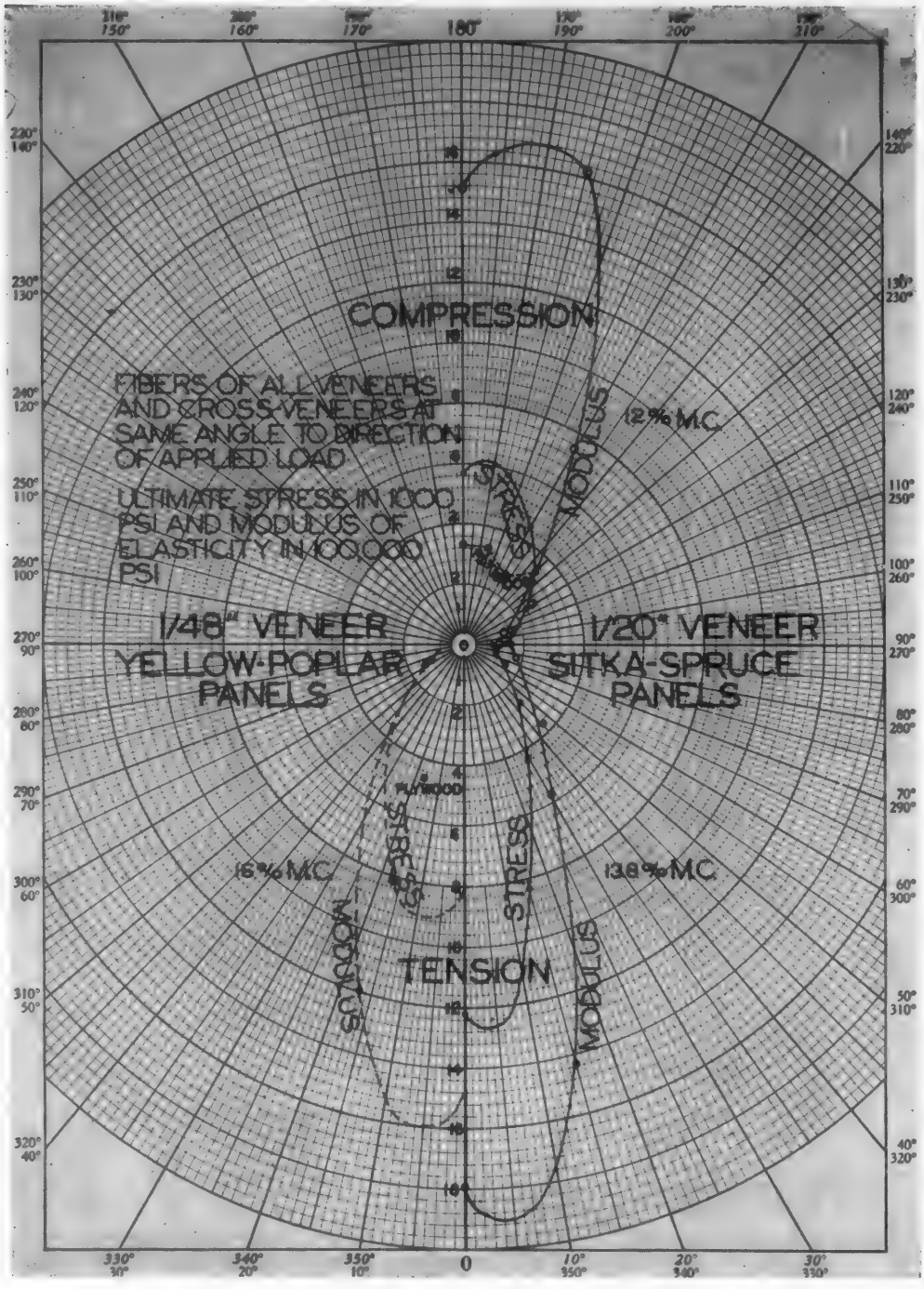


Fig. 11.—Influence of direction of fibers on strength properties of 13-ply 1/48-in. veneer yellow-poplar and 39-ply 1/20-in. veneer sitka-spruce panels.

data for 13-ply panels with seven veneers and six cross-veneers of 1/48-inch yellow poplar (as indicated in Figure 8) and for 39-ply 1/20-inch Sitka-spruce panels are summarized in Figures 11 and 12.

Analysis of the data resulted in the following conclusions:

(1) The moduli of elasticity for the tested panel constructions can fairly accurately be computed by algebraic summation of the moduli for every layer of veneer and cross-veneer. They are not influenced by the presence of butt splices for veneers or cross-veneers. Moduli of elasticity in tension of cross-laminated wood with angles of 5 and 10 degrees between direction of grain and the direction of the applied load were found to be 7 percent larger than those for parallel-laminated wood, presumably as a result of the supporting and reinforcing interaction of adjacent veneers.

(2) The computation of ultimate tensile stresses for plywood constructions with veneer layers having various directions of grain to applied load may be made according to the same principles followed for two-directional plywood, provided consideration is given to any influence of butt splices. The ultimate tensile stresses of cross-laminated wood with angles of 5, 10, 15, and 20 degrees between direction of grain of both veneers and cross-veneers and direction of applied load may be as much as 27 percent larger than those obtained for straight-laminated stock, presumably as a result of the supporting and reinforcing interaction of adjacent veneers. For other types of cross-laminated construction, the ultimate stresses of the individual veneers may be increased as

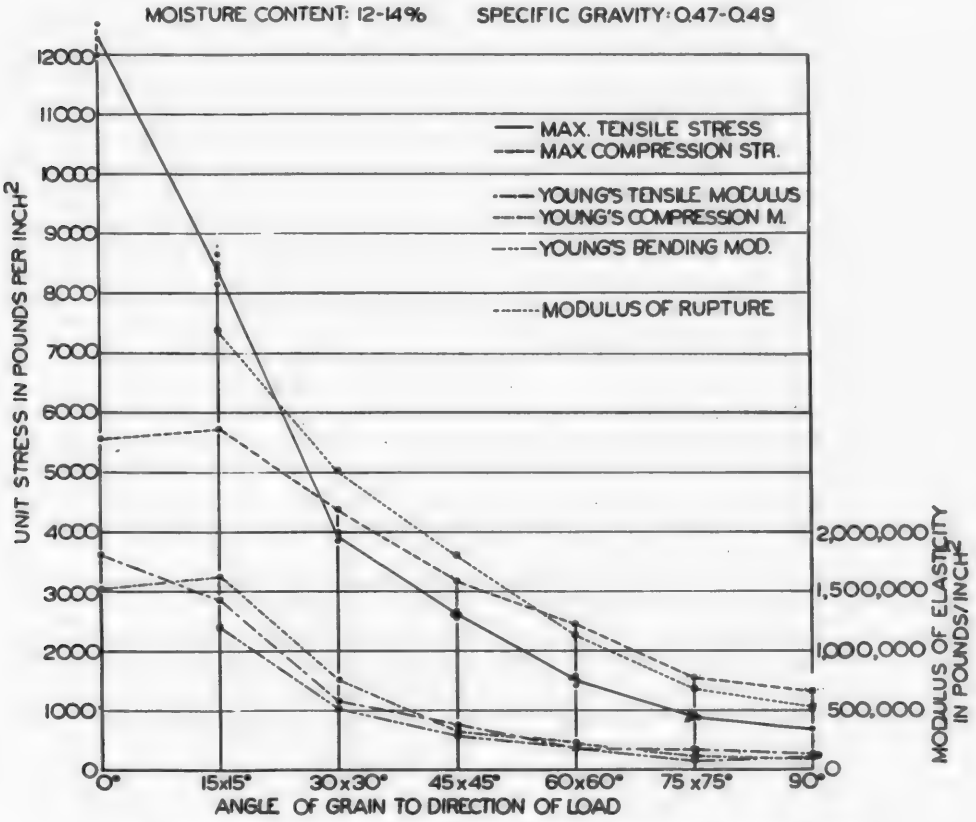


Fig. 12.—Influence of direction of fibers on strength properties of 39-ply 1/20-in. veneer sitka-spruce panels.

much as 40 percent, presumably because of interaction.

(3) Failure of butt-spliced veneers calls for a load transfer from the spliced veneers to the remaining cross-section which, if overstressed, fails at the stress computed for this reduced cross-section. Because of economic considerations, the use of butt splices may be advisable in any type of thick plywood with numerous thin veneer layers, since the influence of the failure of one of many plies to transmit its stress may be relatively small.

(4) Butt splices of adjacent veneer layers should be staggered far enough apart. For 7-ply, 1/32-inch veneer laminated wood and plywood with grain of veneer or cross-veneer in the direction of the applied load, a spacing of ¾ inch proved to be sufficient for 45°-butt splices to allow full utilization of the whole cross-section, despite the discontinuity of veneer or cross-veneer at the butt splice. For plywood with grain or veneer at an angle to the direction of the applied load, a spacing of ¾ inch may not be sufficient for 45°-butt splices.

(5) Non-uniform stress distribution during loading of panels slightly warped because of unbalanced construction may reduce the attained ultimate stresses as much as 95 percent.

In applying the test data to the design of plywood pipe and containers, it should be noted that the construction of plywood for pipe sections does not necessarily have to be balanced, as is required for flat plywood. Hence, any combination of veneers may be employed which may best resist the imposed stresses. Since in certain types of multi-directional panel constructions with continuous grain, the tensile strength of the individual veneers is increased, presumably as a result of the supporting interaction of adjacent veneers, such plywood may be stronger than conventional computations would indicate. In pipes and containers exposed to internal pressures, the influence of compression-perpendicular-to.grain stresses on simultaneously acting tension-parallel-to-grain stresses has not been investigated, although the interaction may strengthen adjacent veneers.

Production Items

The principal items to be manufactured from endless plywood pipe are plywood shipping and other types of containers for the transportation of liquids and solids; for heavy finished products requiring extraordinary protection, such as bombs and other valuable ordnance as well as civilian items, instruments and machinery; for small bulk articles such as nails, bolts, and other hardware; for bulk articles such as flour, feed, seed, food products, fruit, vegetables, and others; for potted flowers and numerous other items calling for care and special protection during transportation. Doubtlessly, plywood containers will not take the place of tin cans. On the other hand, plywood-pipe containers may, under certain conditions, replace barrels, hogsheads, butts, tuns, and kegs, especially where the advantageous strength-weight ratio and tightness of construction are particular assets.

Secondary production items from endless plywood pipe may be listed as follows:

(1) Plywood pipe for pipe lines for the transportation of liquids and gases, thus for water, oil, gas, and sanitary lines. These may be gravity or internal-pressure lines. The resistance of resin-bonded plywood to many chemicals makes such pipe particularly suitable for installation in chemical laboratories and industries. The low thermoconductivity, the high electrical resistance and damping capacity for acoustical and mechanical vibrations are assets if such insulating qualities are required. The light weight of plywood pipe makes it particularly suitable for vents and stacks in tall buildings and, thus, may result in extensive use for air-conditioning ducts. Chutes, such as mail, waste, laundry, and safety chutes, may be effectively constructed of plywood pipe. Splicing may be accomplished in various ways, such as with conical glue, screw, sleeves or flange joints.

(2) Plywood columns for architectural and structural purposes may be used with any desired finish, if wood construction is permissible. Plywood columns with concrete fill, be it plain or steel-reinforced, can be designed for heavy structural supports, making unnecessary the use of any other formwork. Plywood half-shells may serve as temporary re-usable formwork for the construction of reinforced-concrete columns.

(3) Telescoping plywood-pipe radio-antenna masts, carrying cases, tripods, oars, tent poles,

ladders, ski-pole shafts; plywood-pipe ski-pole rings, practice bombs, trouble-light covers, supports for fire-extinguisher bottles have been manufactured and in successful use for several years.[9]

(4) "'Plyfold" structural lumber from plies of wood veneers wound transversely over an oval-shaped mandrel for O-shaped columns and, if split, for U-shaped beams and light fixtures has been visualized.[10]

The schemes described and several others for the production of plywood pipe, containers and drums were developed during World War II in connection with the war effort and in anticipation of using the set-ups for post-war production. Various factors delayed most of the proposals and to date production has been limited despite all the potential markets for the products. It will depend upon the initiative of those interested to sponsor the necessary development work, in order to prove or disprove the feasibility of economical production.

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(9) Anonymous: Resin-Bonded Plywood Tubing. Modern Plastics, Vol. 21, No. 2, October, 1943, pages 81, 82, 142.

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FOREST PRODUCTS RESEARCH SOCIETY

Laboratory Evaluation of Millwork Preservatives

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It is suggested that the method of the National Door Manufacturers' Association for the evaluation of millwork preservatives may be too favorable to the preservative and a modified procedure is described which more nearly approaches practical application. All of the preservatives tested, which include phenyl mercury oleate, pentachlorphenol, and combinations of these and other fungicides, were effective when evaluated according to the N.D.M.A. method.

Introduction

PRIOR to 1935 no organized attempt had been made to find better preservatives for millwork. Because of numerous failures of ponderosa and white pine sash due to blue stain and decay, the sash and door manufacturers employing these species were losing business to metal sash and to sash made from naturally durable woods. In order to improve the durability of pine millwork, the Western Pine Association initiated studies in 1935 to develop satisfactory preservatives to prevent decay and blue stain. As a result of these studies, Hubert[2] recommended pentachlorphenol, tetrachlorphenol, 2-chloroorthophenylphenol and orthophenylphenol as satisfactory for millwork treatment. He also proposed a set of minimum standards for compounds suitable as millwork preservatives.

As early as 1937, sash and door manufacturers began to use the various chlorphenols, alpha-nitronaphthalene and beta naphthol. In order to standardize the treating procedure and to establish the most effective compounds available, the National Door Manufacturer's Association organized a committee to formulate a set of minimum standards to be followed by millwork manufacturers in treating their products. The committee developed a laboratory test method for the evaluation of non-swelling, oil-soluble preservatives and on the basis of their cooperative studies formulated a set of minimum standards for millwork preservatives.[3] These standards formed the basis of "the seal of approval" program of the N.D.M.A. All members of the Association who treated their millwork according to these standards were authorized to apply the Association's seal to their products.

Without doubt, this program has been a step forward in the production of more durable and improved millwork. In addition, the millwork program and wartime problems have further stimulated the use of the newer organic preservatives in other applications where resistance to decay and blue stain is important.

Although today's shortages in building materials have encouraged the acceptance of untreated wood for many uses where treated wood would be desirable, many manufacturers are recognizing the need for adequate treatment to effectively compete with metal. The natural beauty of wood, its excellent insulating properties, low heat conductivity, light weight, availability, low cost, ease of replacement, absence of corrosion, and workability are enviable advantages. However, for wood to maintain and expand its position in such applications as millwork, auto and truck bodies, railroad cars, boats, and building construction, adequate protection against fungus deterioration is essential. Manufacturers of wood products and of wood preservative chemicals are active in this work. As a result of their research, gradual change and improvement in the preservatives and extension of their use to other fields can be expected.[1]

This report summarizes the evaluation of promising preservative compounds when tested by the method of the N.D.M.A. and by a modified method. It is suggested that additional research is required to develop an improved

laboratory method for the evaluation of millwork type preservatives by modifying the N.D.M.A. method so that it will more nearly approach practical application.

Test Methods

The "N.D.M.A. Method of Testing Oil-soluble Wood Preservatives for Toxic Properties Using Wood Blocks Uniformly Impregnated" is described in detail by Hubert.[3] In brief, after being conditioned to equilibrium and weighed, kiln-dried ponderosa pine sapwood blocks, 0.64 cm. thick (longitudinal direction) by 3.5 cm. on the radial surface (edge grain) and 5.09 cm. on the tangential surface (flat grain), are impregnated under vacuum at 125± 2 mm. of mercury. After obtaining the treated weight to determine the absorption of preservative, the blocks are reconditioned and reweighed. One set of blocks is treated with one-half of the recommended concentration of the chemical. A second set is treated with the recommended dosage of the chemical and volatilized at 160 degrees F. for 24 hours. Half of the volatilized set is then leached. After reconditioning, the blocks are placed on cultures of the decay fungus, *Lenzites trabea* (FPL 617) and of the blue stain fungus, *Hormiscium gelatinosum* (FPL 595). The decay blocks are placed on glass rod supports, resting on the surface of the fungus mat. The blue stain test blocks are placed directly on the fungus mat.

After incubation at 26–28 degrees C. for 63 days, the decay blocks are removed and the oven-dry weights obtained. The weight loss due to decay is computed from the final and the calculated initial oven-dry weights. The blocks in the blue stain test are evaluated visually as either clear or stained.

Results obtained from the test carried out by this N.D.M.A. procedure suggested that a more accurate evaluation of millwork preservatives might be obtained by a method which more nearly approached commercial treating practice. The method described below was adapted from that developed by M. W. Baker and E. A. Patton of the Curtis Companies, Inc. This test was exploratory only, and the modified method used is suggested merely as a step toward the development of an improved laboratory procedure for evaluating millwork type preservatives.

Kiln-dried ponderosa pine sapwood blocks, 1 inch thick (longitudinal direction) by 2 inches on the radial surface (edge grain) by 2.5 inches on the tangential (flat grain) surface (as contrasted to the smaller specimens called for in the N.D.M.A. method), were dip-treated for three minutes at a depth of four inches below the surface of the treating solution. Some of the treated blocks were volatilized by the same procedure as used in the N.D.M.A. method. A set of the volatilized blocks was then leached by a procedure considered to be more convenient than that used in the N.D.M.A. test. The blocks were placed in quart jars and leached for 24 hours with running water at 30 degrees C. at the rate of nine liters per hour.

Instead of employing a nutrient agar culture of the test fungus, the blocks were placed on a bed of three 2.5-inch squares of glass cloth, sterile distilled water was added to the jar to provide moisture, and one week later an inoculum block of ponderosa pine sapwood was placed on top of the test block. The 0.25-inch cross section inoculum blocks were previously infected with the test organism by placing them on cultures of the test fungus for a period of one month. Since no definite data are available regarding optimum moistures for the decay of ponderosa pine with *L., trabea,* enough water was added to different jars to provide calculated moistures of 75 to 125 percent in the test blocks. The jars were incubated at 80 degrees F. for 63 days and the weight loss due to decay determined by the method recommended in the N.D.M.A. procedure.

Only a decay test with *L. trabea* was carried out with this modified procedure. The method should also be suitable for a blue stain test. A comparative N.D.M.A. test employing the same preservative treatments was run concurrently. The only change in the regular N.D.M.A. method was that the leaching of the selected set of blocks was accomplished by the modified procedure described above.

Special wide-mouth, pint, mason jars were used in all the tests. The zinc caps were turned on loosely to permit exchange of air. In all cases both treated and untreated blocks were

TABLE 1.—PERFORMANCE OF VARIOUS PRESERVATIVE TREATMENTS EVALUATED BY THE N.D.M.A. METHOD

Code	Treatment[1]	Percent active in treating solution	Absorption of active lb./cu. ft.	Percent weight loss due to decay[2]			Percent blue stain on block surfaces[2]					
				Original	Volatilized	Volatilized and leached	Original top	Original bot.	Volatilized top	Volatilized bot.	Volatilized and leached top	Volatilized and leached bot.
1	Phenyl mercury oleate	0.1	0.015	+0.2[4]	+0.4[4]	0.4	0	22	0	11	0	32
2	Phenyl mercury oleate[5]	0.1	0.013	0.2	+0.1[4]	0.1	0	32	0	5	0	50
3	Pentachlorphenol[6]	2.5	0.425	0.2	0.4	0.4	0	4	0	27	0	26
4	Pentachlorphenol[7]	2.5	0.337	0.3	0.1	0.3	1	63	3	34	0	65
5	Phenyl mercury oleate[3] Pentachlorphenol[6]	0.05 0.5	0.09	+0.4[4]	0.1	0.0	0	20	0	27	0.7	34
6	Phenyl mercury oleate[3] 2,4-Dinitrophenyl-thiocynate[8]	0.05 0.5	0.088	0.0	0.4	+0.7[4]	0	6	0	5	0	11
7	Phenyl mercury oleate[3] Zinc naphthenate[9]	0.1 1.0 Zn	1.665	+0.6[4]	0.3	+0.2[4]	0	0	0	1	0	0.3
8	Phenyl mercury oleate[3] Pentachlorphenol[6] IN 7677[10]	0.075 0.75 0.075	0.094	+0.2[4]	0.3	+0.7[4]	0	14	0	12	0	23
9	Phenyl mercury oleate[3]	0.5	0.081	0.1	0.2	+0.3[4]	0	0	0	0	0	0.1
10	Untreated	0.0	0.0	30.7	25.5	30.0	65	87	39	54	42	84

1 = In Atlantic Refining Co. No. 52 Stoddard solvent.
2 = Each figure an average of 7 blocks; 14 blocks in No. 10.
3 = From Fungicide IN-2555, Grasselli Chemicals Department, du Pont Company.
4 = "+" denotes gain in weight.
5 = From RK 402 Rot Inhibiting Sealer (containing 24% alkyd resin vehicle) F. & F. Division, du Pont Co.
6 = Monsanto technical grade Santophen 20, Lot T-110.
7 = Permatox WR (water repellent toxic), Chapman Chemical Co.
8 = Used 0.5 percent Sun Oil Solvent No. 1547 as booster solvent.
9 = Socony Vacuum Oil Co. 800s (8 percent metallic zinc).
10 = An organic arsenic compound. Used 1.0 percent acetone as booster solvent.

steam sterilized at atmospheric pressure at 100 degrees C. for 20 minutes before placement on the culture mats, or before placement of the inoculum block, as in the modified method.

Results of Single and Combination Treatments when Tested by the N. D. M. A. Method

In many instances fungicidal compounds, which are highly effective against a great many fungi, are much less effective against one or more tolerant kinds. These tolerant forms may therefore limit the range of utility of such preservatives. On the other hand, combinations of two or more compounds which complement one another in their effectiveness against different fungi should provide treatments with greater all-round efficiency.

Since such combinations may offer increased effectiveness, reduced irritation and toxicity, lower costs and easier handling, combinations of compounds were tested along with some of the individual fungicides. The results (Table 1) show that all of the treatments used were effective in the decay test. The most effective preservatives in the blue stain test were phenyl mercury oleate at 0.5 percent and a combination of phenyl mercury oleate (0.1 percent) and zinc naphthenate (1.0 percent metallic zinc).

Exactly what degree of effectiveness can be accepted as satisfactory in the blue stain test is debatable. The N.D.M.A. method states that the blocks should be rated as either clear or stained. Since the test blocks are placed directly on the blue stain culture, it is almost inevitable that there will be some attachment of the fungus to the underside of the block. If the rating is limited to the upper surface, there is little choice among the treatments. These readings were checked microscopically to be sure that the discoloration on the upper surfaces was caused by blue stain. In some cases microscopic examination showed that discolored areas that would probably be mistaken for blue stain were actually caused by accumulation or discoloration of resinous materials. These difficulties in accurately evaluating performance of preservatives against blue stain by the N.D.M.A. method suggest that a modified procedure is desirable.

In considering the advisability of modifying the N.D.M.A. method to reduce possible discrepancies in evaluation and to have the test more nearly approach practical application, the following questions are raised on the method of treating. In actual practice finished millwork is dip-treated for three minutes. In the N.D.M.A laboratory method, 0.25-inch cross sections are treated under a vacuum of 125 ± 2 mm. of mercury. Such treatment may unduly favor the experimental preservative, even though some of the blocks are subsequently subjected to relatively severe volatilization and leaching.

To check the effect of such loading of the test blocks with the preservative, isolations were made from the bottle cultures after the test was completed. Blocks treated with 2.5 percent pentachlorophenol (No. 3 in Table 1) and 0.5 percent phenyl mercury oleate (No. 9) gave off sufficient toxic vapors to kill[4] the decay fungus, *L, trabea* (Table 2). Similar killing occurred in some of the other treatments with the blocks which were neither leached nor volatilized. *H. gelatinosum* was more tolerant to the fungicides, although some of these cultures were also killed.

If the fungus is killed soon after the test is started, no attack can occur even though sufficient chemical might be lost through volatilization to permit attack later in the incubation period. One would not expect to have a similar accumulation of vapors in practice. The importance of this apparent weakness in the test method may not be too serious, since the lower dosage of 0.1 percent phenyl mercury oleate did not kill the test fungi but nevertheless performed satisfactorily. However, it seems desirable to have a test method which will avoid the accumulation of unnatural vapor concentrations.

Comparative Results with the N. D. M. A. Method and the Suggested Modified

In the N.D.M.A. test the decay fungus is initially handicapped by having to attack a dry block. Actually *L. trabea* will readily wet and attack an untreated block, even when the block is placed over it on a glass rod support. The wetting of the block is accomplished by the fungus growing over the block and "wick-

ing" the necessary moisture for decay into the block. Similarly to attack and wet a dry block carrying a heavy load of preservative may be another matter. On the other hand, if the treated block initially contained an optimum amount of moisture for decay, the fungus might have a better chance and the conditions would more nearly approximate natural exposures of sash. The results of the exploratory method do not prove that this is true, but they do point out the feasibility of supplying optimum moistures for decay in laboratory tests.

The results of the second N.D.M.A. test are summarized in Table 3. Three sets of blocks, as called for in the N.D.M.A. method, were prepared for treatments Nos. 1 and 3. Only the volatilized and leached set was prepared for treatments Nos. 2, 4, and 5, since the results obtained with this set would ordinarily determine whether or not a given treatment was satisfactory. All of the treatments were satisfactory in the decay test and, if they are rated on the basis of blue stain on the upper surface only, all were equally satisfactory in the blue stain test.

The desirability of providing optimum moistures in the test blocks is supported by the fact that the untreated blocks had final moisture contents averaging about 250 percent (Table 3). On the other hand, the treated blocks averaged but 30 to 48 percent moisture.

Apparently the moisture supplied the larger blocks in the modified test was insufficient to provide an optimum moisture content for decay (Table 4). Snell[5] has reported that the optimum moisture for decay with certain fungi in woods of low specific gravity is about 150 percent. Since the untreated blocks in the N.D.M.A. test had an average final moisture content of 250 percent, the optimum moisture for decay of ponderosa pine with *L. trabea* may be 200 percent or greater.

The results of the modified decay test are inconclusive, because of the low and inconsistent losses in weight in the untreated blocks (Table 4). Actually the variation in weight losses was not much greater than in the untreated blocks in the regular N.D.M.A. test, but the total average loss is too low to be considered reliable. The percent weight loss, final moisture content, and visual growth of the fungus for each untreated block in the modified test is recorded in Table 5. Except for blocks 6C–3 and 6C–4, which had only light fungus growth, there may be some correlation between weight loss and moisture content. Increasing the moisture content to 200–250 percent for ponderosa pine and extending the incubation period, because of the larger blocks used, should improve the modified method. If satisfactory results can then be obtained in the untreated blocks and the treated blocks

TABLE 2.—EFFECT OF PRESERVATIVE TREATMENT ON THE VIABILITY OF THE TEST FUNGI (N.D.M.A. METHOD)

Code	Treatment[1]	Percent active in treating solution[2]	Condition of the culture after 63 days' incubation[3]					
			Lenzites trabea[4]			Hormiscium gelatinosum[4]		
			Original	Volatilized	Volatilized and leached	Original	Volatilized	Volatilized and leached
1	Phenyl mercury oleate	0.1	+	+	+	++	++	++
2	Phenyl mercury oleate	0.1	+	+	+	++	++	++
3	Pentachlorphenol	2.5	—	—	—	+—	++	++
4	Pentachlorphenol	2.5	—	—	+[5]	++	++	++
5	Phenyl mercury oleate	0.05	—	+	+	++	++	++
	Pentachlorphenol	0.5						
6	Phenyl mercury oleate	0.05	+	+	+	++	++	++
	2,4-Dinitrophenyl thiocyanate	0.5						
7	Phenyl mercury oleate	0.1	—	+	+	+—	++	+c[6]
	Zinc naphthenate	1.0 Zn						
	Phenyl mercury oleate	0.075						
8	Pentachlorphenol	0.75	+	+	+	++	++	++
	IN–7677	0.075						
9	Phenyl mercury oleate	0.5	—	—	—	+—	++	—+
10	Untreated	0.0	+	+	+	++	++	++

1—See Table 1 for reference notes on treatments.
2—See Table 1 for absorption in lb./cu. ft.
3—"+" = culture alive; "—" = culture dead.
4—One isolate for each treatment with L. trabea; two isolates for each treatment with H. gelatinosum.
5—Growth was abnormal.
6—"c" = contaminated, no growth of H. gelatinosum.

TABLE 3.—PERFORMANCE OF VARIOUS PRESERVATIVES AND FINAL MOISTURE-CONTENT OF THE DECAY TEST BLOCKS (N.D.M.A. METHOD)

Code	Treatment[1]	Percent active in treating solution	Absorption of active lb./cu. ft.	Weight loss due to decay[2]			Final moisture content of the decay blocks[3]	Amount of blue stain on block surfaces[2]					
				Original	Volatilized	Volatilized and leached		Original		Volatilized		Volatilized and leached	
				Percent	Percent	Percent	Percent	Top Percent	Bot. Percent	Top Percent	Bot. Percent	Top Percent	Bot. Percent
1	Phenyl mercury oleate[4]	0.125	0.014	+0.9[5]	------	------	41.2	0.0	12.3	---	---	---	---
	Phenyl mercury oleate[4]	0.25	0.038	------	+1.1[5]	+1.2[5]	46.0 and 32.2[6]	----	----	0.0	0.8	0.0	19.3
2	Pentachlorphenol[7]	5.0	0.844	------	------	+1.7[5]	37.7	----	----	---	---	0.0	31.0
3	Pnenyl mercury oleate[4]	0.05	0.089	+0.9[5]	------	------	41.3	0.0	13.3	---	---	----	----
	Pentachlorphenol[7]	0.5											
	Phenyl mercury oleate[4]	0.1	0.163	---	+1.0[5]	+0.5[5]	48.3 and 30.4[6]	----	----	0.0	3.0	0.0	3.6
	Pentachlorphenol[7]	1.0											
4	Phenyl mercury oleate[4]	0.1	0.242	---	---	+1.8[5]	30.2	----	----	---	---	0.0	6.5
	Pentachlorphenol[7]	1.5											
5	Phenyl mercury oleate[4]	0.1	0.164	---	------	+1.1[5]	39.7	----	----	---	---	0.0	6.3
	IN-8573[8]	1.0											
6	Untreated	0.0	0.0	21.8	------	36.4	243 and 254[6]	45.8	74.1	---	---	59.1	80.0

[1] = In Atlantic Refining Co. No. 52 Stoddard solvent.
[2] = Each figure is an average of 6 blocks.
[3] = These averages exclude an occasional block which had fallen onto the culture and absorbed moisture from the agar.
[4] = From Fungicide IN-2555, Grasselli Chemicals Department, du Pont Company.
[5] = "+" denotes gain in weight.
[6] = The first figure is for the volatilized set; the second for the volatilized and leached set.
[7] = Monsanto technical grade Santophen 20, Lot T-110.
[8] = A quaternary ammonium chlorophenolate. Used 50:50 xylol and Stoddard solvent for No. 5.

TABLE 4.—WEIGHT LOSS AND FINAL MOISTURE CONTENT OF THE TREATED BLOCKS (MODIFIED DECAY TEST)

Code	Treatment[1]	Percent active in treating solution	Absorption of active lb./cu. ft.	Milliliters water added to culture jar	Final moisture content[2]			Weight loss due to decay[2]		
					Original Percent	Volatilized Percent	Volatilized and leached Percent	Original Percent	Volatilized Percent	Volatilized and leached Percent
1	Phenyl mercury oleate[3]	0.25	0.0025	35	---	94	102	------	+1.0[4]	+1.6[4]
				45		148	154	------	+0.5[4]	1.5
2	Pentachlorphenol[5]	5.0	0.075	35	104	---	110	+0.3[4]	------	2.1
				45	---	---	153	------	------	+1.3[4]
3	Phenyl mercury oleate[3]	0.1	0.012	35	---	108	120	------	+1.3[4]	+0.9[4]
	Pentachlorphenol[5]	1.0		45	---	126	129	------	+3.4[4]	+2.5[4]
4	Phenyl mercury oleate[3]	0.1	0.022	35	102	---	101	+1.9[4]	------	+2.5[4]
	Pentachlorphenol[5]	1.5		45	---	---	155	------	------	+2.9[4]
5	Phenyl mercury oleate[3]	0.1	0.009	35	---	105	100	------	+1.0[4]	1.5
	IN-8573[6]	1.0		45	---	---	159	------	------	+1.2[4]
6	Untreated	0.0	0.0	35	149	---	124	8.2	------	8.5
				45	147	---	165	5.1	------	0.3

[1] = In Atlantic Refining Co. No. 52 Stoddard solvent.
[2] = Each figure for Treatments 1, 3 and 6 is an average of 4 blocks with 35 ml. water and 1 block with 45 ml. water.
Each figure for Treatments 2, 4 and 5 is an average of 2 blocks with 35 ml. water and 1 block with 45 ml. water.
[3] = From Fungicide IN-2555, Grasselli Chemicals Department, du Pont Company.
[4] = "+" denotes gain in weight.
[5] = Monsanto technical grade Santophen 20, Lot T-110.
[6] = A quaternary ammonium chlorphenolate. Used 50:50 xylol and Stoddard solvent for No. 5.

TABLE 5.—FINAL MOISTURE CONTENT, AMOUNT OF FUNGUS GROWTH, AND WEIGHT LOSS OF THE UNTREATED BLOCKS TESTED BY THE MODIFIED METHOD

Code	Treatment	Block No.	Final moisture content Percent	Visual growth of L. trabea on block	Weight loss due to decay Percent
5A	Untreated (not volatilized or leached)	1	182	Heavy	17.7
		2	152	Heavy	6.5
		3	147	Heavy	5.1
		4	145	Heavy	7.7
		5	114	Heavy	1.0
					Av. 7.6
6C	Untreated (volatilized and leached)	1	123	Heavy	7.6
		2	125	Heavy	18.5
		3	165	Slight	0.3
		4	91	Slight	0.0
		5	159	Heavy	13.1
					Av. 6.9

still provide suitable resistance to decay and blue stain, the method may be more indicative of service performance than the N.D.M.A. method. Additional tests are required to establish whether these modifications will provide a more accurate evaluation of millwork type preservatives.

Discussion

On a performance basis, all of the treatments evaluated by the N.D.M.A. method were promising for the preservation of millwork against decay and blue stain. Combinations of phenyl mercury oleate with pentachlorphenol, zinc naphthenate, 2,4-dinitrophenyl thiocyanate, and other combinations of these and additional fungicides may offer special advantages. Such combinations may provide greater all-around efficiency, reduce irritation in handling the preservative and the treated product, reduce costs of treating, and improve permanency.

It is suggested that the present N.D.M.A. method may unduly favor the preservative and that a test procedure more nearly approaching practical application is desirable. A modified procedure employing larger blocks, a short dip treatment, and optimum moisture content in the test blocks may provide a more reliable indication of the effectiveness of a given treatment. The glass cloth method described offers a simple means of supplying practical optimum moisture contents. Such a method necessitates knowing the optimum moisture content for decay with a given test fungus in a given species of wood. Such information is not only desirable but, when applied, it should permit more accurate laboratory evaluation of decay resistance.

One question that seems worth considering is the extent to which water repellent and sealer materials impede absorption of the preservative when they are applied as a single dip treatment. In treatments No. 2 and 4 (Table 1) absorption of the preservative was less than in treatments No. 1 and 3. In addition to impeding absorption of the preservative, the water-repellent solids may further interfere with preservative efficiency by coating the fungicide particles and rendering them essentially innocuous. This type of effect has been encountered in this laboratory on fabric treated with a combination water repellent and fungicide.

In the interest of developing satisfactory preservative treatments for such items as millwork it is desirable to investigate further: (1) whether water-repellent solids interfere with the absorption and efficiency of a preservative when applied in combination; (2) whether a more practical laboratory test method would not provide a more reliable indication of service performance; and (3) whether other compounds and combinations of compounds will provide greater effectiveness than those now in use. One failure in wood sash may turn several potential customers to metal sash. Recognizing the greater hazards involved in present construction, because of increased condensation from humidified heating systems and because of the increased utilization of non-durable sapwood, the need for adequate preservative treatments for the successful use of wood in sash is obvious.

It is hoped that the results and discussion presented here will stimulate additional research in developing improved testing procedures and maintaining adequate and satisfactory preservative treatments for millwork and similar applications.

Summary

When tested by the N.D.M.A. method, 0.1 percent phenyl mercury oleate, 2.5 percent pentachlorophenol, and various combinations of phenyl mercury oleate with pentachlorphenol, zinc naphthenate, 2,4-dinitrophenyl thiocyanate, an organic arsenical and a quaternary ammonium chlorophenolate were all found to be effective.

It is suggested that the N.D.M.A. method favors the preservative because of the heavy dosage applied and because optimum moisture contents for decay are not attained. Blocks treated with 2.5 percent pentachlorphenol and 0.5 percent phenyl mercury oleate emitted sufficient fungicidal vapors to kill the decay fungus, *L. trabea*. The blue stain fungus, *H. gelatinosum*, was more tolerant to these fungicides, although some cultures of this organism were also killed.

Difficulty was experienced in accurately determining the effectiveness of a preservative against blue stain by the N.D.M.A. method. It seems desirable to elaborate on the N.D.M.A. requirement which states that the blocks are evaluated as either clear or stained.

A modified procedure is described which employs a large block, a short dip treatment, and a means of supplying practical optimum moisture contents for decay. This procedure more nearly approaches practical application and it may provide a more reliable indication of the probable service performance of millwork type preservatives. Additional experiments are necessary to establish the utility of the modified procedure.

Limited evidence suggests that the water-repellent solids in a combination water repellent toxic interfere with the absorption and preservative efficiency of the fungicide. Additional research is suggested to determine (1) the extent to which the repellent solids may interfere with preservative efficiency, (2) whether a more practical laboratory test method will provide a more reliable indication of service performance, and (3) whether other compounds and combinations of compounds will provide greater effectiveness than those now in use.

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Wood—Where Are We Going?

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BEFORE looking into the crystal ball of the future in any field, it is well to reflect on the past, analyze the present, and then, with these facts at hand, carefully plot the course in the future, hoping as nearly as practical to take wise counsel from the past and present so that a sounder future, built upon the successes of the yesterday and today, free from as many of the obvious errors previously made may be an attainable goal. In the wood industries our theme is "Wood—Where Have We Been, Where Are We Today, and Where Are We Going?"

The first records of man deal with wood. It was in the Garden of Eden that the fruit of a certain tree caused man to be ejected from Paradise and doomed to roam the earth, left to his own devices to sustain himself. Wood must have been sorry for man because it became his material companion through the ages. From the date of that earliest of records, the history of the civilization of man and of wood and its products has been a parallel story. Wood was the first natural resource upon which man fell to provide shelter, warmth, tools, weapons and agencies of comfort, such as primitive furniture. It later made the boats which made it possible for the early nomadic tribes to cross bodies of water. Having made water transportation possible, wood also contributed the greatest mechanical gifts of ancient times; to land travel, the wheel; and to the builders, the wedge. As the history of man spread westward and northward, wood was ever present. There were times when stone and masonry appeared to be pushing wood out of the picture, but wood always came back. In pre-Colonial days in England the navy owned all the oak. It was a capital offense to cut down an oak tree, as the strength of England depended upon ships and ships depended upon wood.

Although the actual discovery of America is attributed to a desire to find a short cut to India for spices and oriental goods, and the exploitation of parts of this country resulted from the lust for gold, one of the most significant reasons for the desire to establish colonies in the Virginia area was the forests, and shortly after settlements were made a lively trade in timber and lumber was set up. Colonial America was a land of wood. It was the largest single material available to promote colonization and expansion. Man progressed in his knowledge of wood and how to utilize it. In the organized communities it provided the material to build homes; on the frontiers it was material for forts and stockades that afforded protection against the savages. Colonial America had brick, masonry, iron and other materials, but wood was the universal material and there was an abundance of it. The basic simplicity and utility of the early home designs of that day have lived, and even today their style is copied and reproduced, not only in the home itself, but in the furniture designs of the master craftsmen of that day. This certainly was a golden age in wood.

As America became more and more an industrial nation, the use of metals grew and grew. Many were the prophets of doom for wood. Designers vied with each other to make articles of metal to supplant those of wood;—steel beds, brass beds, cast iron chairs and benches, nobody wants wood any more. But didn't they? Wood came back because wood has one thing that could not be built into the substitutes; it was the product of a form of life. It had lasting beauty and, when the cycle ran its normal course, wood again took its rightful place. It is natural that many uses for wood were supplanted by the advent of metals,

* An address presented at the meeting of the Northeastern Section, Forest Products Research Society, held in New York City on February 27, 1948.

such as structural materials, but as the country grew the demand for wood and its products grew faster, so that the loss to metallic products did not reduce its total use.

As we carry this progress up to the present day we have seen this cycle repeat itself many times, and each time after the cycle has run its course wood emerges stronger and a more vital part of our needs and our economy than ever before. Just before the last war we were in one of those "make it out of anything but wood" cycles, and then came Pearl Harbor. From that day wood and its products became one of the most critical materials required for the war effort. The problems of wood procurement need no elaboration as practically all of us here know what we were up against.

That is where we have been. Now, where are we today? What is the greatest post-war need in our nation. Homes for its people! What material is the most necessary to build homes. Wood! The same material that man used in the earliest days of his civilization to provide shelter and comfort is required to shelter and comfort us today. Nature has abundantly provided this material and we have provided the facilities to utilize it for our needs. So wood today is of greater importance to our social economy than ever before.

Today the uses and products of wood are multifold, more so, probably, than any other simple basic natural raw material. This, naturally, results in a tremendous diversification of the industries using wood as a basic raw material. The units vary in size from the enormous paper mills to the small cabinet maker, each depending upon wood. We have sawmills producing hundreds of thousands of feet daily and small ground mills doing five to ten thousand feet daily. All are producing products of wood. We have a wide range of products in wood caused by the geographical expanse of our country which affords many species of wood, giving the industry a range of products available to few nations of the earth. The presence of wood in practically all parts of this country has made possible the thousands of small businesses working in wood. The wood industries have not had the problem in raw material that prevails in iron, where deposits of ore are confined to reasonably limited areas, which require concentration of operations at those certain areas and at points where the raw materials must be shipped to be processed economically with other essential raw materials such as coal to produce a usable product. Nature does not give us iron as a usable iron, it must be smelted and passed through many processes before it is ready for use. Such a process requires large units and large capital investment. Nature has been kinder to us. Wood is practically everywhere, and if we intelligently use it it will continue so. Nature has also given us a material that in itself is practically complete. A tree produces lumber. The basic material is used, for the greatest part, as wood, as nature gave it to us. Fundamentally little investment is required to process it from the tree to lumber and it can be done with very few exceptions all over the nation.

The wood industries are essentially small businesses and to a great extent have been dominated by a thorough, individualistic approach to the economic problems of the industry. The larger units have had associations in which the material problems of the industry have been studied, but, with the exception of the areas where the larger and more concentrated productions of a type of product occurred, there has not been a medium of mutual exchange of ideas and mutual understanding of the economics of the industry available to all. This lack of organization and mutual understanding has, to a great extent, been responsible for the high rate of economic mortality that has been so prevalent in the wood industries. We do not see the same rate of economic mortality in the more concentrated industries. By mutual association and free interchange of ideas they have all benefited. In discussing industry organization herein, I am not referring to price fixing and other allied ills that have unfortunately been the prime reason for some associations. I mean specifically the type of association that serves the public as well as the producer, the type of association that will bring men's minds together to widen markets, increase quality, and reduce the costs of goods through sound economic planning, research and engineering.

The needs of the wood industries today are many, but in general, to solve the problem, an

association covering the entire wood field as a nucleus should be operative. Such an organization would be interested in one thing — WOOD. It would embrace every phase of our industrial life that depended upon wood. Under this general organization would come the important component organizations covering the different major industrial classifications, such as paper, lumber, furniture, mill work, plywood and so forth. Then each of these groups would be thinking of wood, but more especially as it pertained to their particular major classification. Each of these groups would then be further decentralized into specific industrial groups, whose problems would be similar and whose conditions the same, with geographical sub-divisions enabling a spread of effectiveness that even the smallest worker in wood could be served and benefited. All would be thinking of wood, but then, not only as it affected him as a small or large unit, but how it could be beneficial to the whole industry and to the nation as a whole.

Such an organization should carry on research of many different kinds. Research that would result in greater utilization of our forests. Research that would assist in the development of new products. Research that would find markets for waste products of one group through conversion into the products of another group. Today there are many producers of wood products that are purchasing prime raw material when by-products or waste from many plants would suffice, and the by-products are being burned in refuse burners because no apparent market exists. The economic possibilities of this one phase of research alone are tremendous.

The fact that a large percentage of the wood industries today do not have cost knowledge is indisputable. On the surface this may sound presumptive, but surveys have proved it to be so. Why does this condition exist? It is because the job can't be done, or is it because the job hasn't been done? It is the latter. During the period of the N. R. A., in order to establish prices cost information had to be gotten. It was surprising how quickly industrial groups who had no uniform costs developed simple cost formulae which were remarkably accurate. Research of this nature would be of immeasurable value and would provide a small operation with the economic tools that he needs yet cannot, as an individual, afford to purchase.

Equipment Research is most necessary. The general processes in the wood-working industries have changed little in the last decade. Machines have been refined, tools improved, but, fundamentally, we are still buying yesterday's machines. What kind of machines would we buy if a group sat down and soundly discussed a process or series of processes. I venture to say the equipment that would result would revolutionize many segments of this industry. Just consider what has happened in the automotive industry.

Research in Employee Relationships is most essential. Today, with our plants from one end of the country to the other, we are beset with other industry patterns, area patterns, geographical differentials and the like. What is the pattern for labor or employee relationship in our industry? We should have it. The full knowledge of wages, working conditions, employee benefits and other elements of labor relations should be understood so that a business, small or large, in our industry will know what the pattern is. Without such knowledge, good bargaining for sound and beneficial employee relationship is not possible.

These are a few of the things that our industry needs today, as I see it. They could all be achieved in time by good, sound organization that would embrace all the segments of the wood industries. Being an all-embracing organization, the cost to each could be very low and many times overshadowed by the benefits.

Where are we today? We are on the threshold of tomorrow. Wood! Where are we going? We have the choice of the errors of the past or the opportunity of the future. We have a bountiful nature to replace our raw material, a material that has life and beauty, a material which, if intelligently administered, will bring shelter, comfort, livelihood and joy to the peoples of the world. Wood! Where are we going? It is up to us in the wood-working industries, banded together in common purpose, to chart the course safely into a secure future.

Wood! That's where we are going!

BUSINESS MEETING

The meeting was called to order by President Gottschalk at 5:00 P. M. on Tuesday, March 23 following the conclusion of Technical Session II. The President stated that the membership was nearing 1300 but emphasized that a much larger membership is needed to enable the Society to carry out its obligations and take full advantage of its opportunities for service. He also announced the recent establishment of the grade of student (associate) membership at annual dues of three dollars.

Abstracting Committee

Mr. Charles B. Hemming presented the report of the Abstracting Committee as follows:

This committee consists of:

Charles B. Hemming; Chairman
Dr. G. J. Esselen
Mr. J. E. Lodewick
Professor A. J. Panshin

Because of the press of duties, Mr. S. G. Smith recently found it necessary to resign. We have asked Mr. R. M. Brown, Supt., Forest Products Laboratory, University of British Columbia, to serve in his stead.

In rendering this report we wish to acknowledge the valuable assistance and advice of Mr. F. W. Gottschalk, Dean George A. Garratt and others who have taken a keen interest in our work.

The Abstracting Committee proposes the following program as appropriate in initiating an abstracting service to Society members in keeping with the Society's current ability to support such a program.

1. Call for voluntary abstractors to serve without fee.
2. Keep the load of each abstractor small to avoid any undue burden on any individual and to insure prompt submission of abstracts.
3. Limit publications to be abstracted to relatively inaccessible periodicals and new books, possibly at the very start abstracting foreign publications only.
4. Expand the Society home office facilities to handle the editing and forwarding of the abstracts. (We understand that this expansion is necessary and contemplated for other reasons.)
5. Publish the abstracts in the magazine *WOOD*. (This will make the abstracts available without cost of non-member readers of *WOOD* but is considered good advertising during the initial period.)
6. Arrange for a fixed amount of space in *WOOD* to be used completely or not at all. In this connection, a back log of abstracts should be built up to draw on in the event of lean periods.
7. Purchase periodicals as necessary limiting expenses from this source and incidentals to $500.00 for the first year.
8. Limit abstracting very sharply to the direct subject "Forest Products" during the initial period.

In arriving at these recommendations the committee has studied a considerable mass of ideas and suggestions which have been boiled down to what we believe is an appropriate program. In making the recommendations we wish to limit it to a maximum of one year as we expect to learn by experience and to alter our recommendations as the need arises.

The Committee Members are unanimous in making these recommendations and, if it is in order, would like to have our President entertain a motion that this program be adopted.

This was moved by Mr. Hemming, seconded by Mr. Tigelaar and passed without dissent.

Publications Committee

Mr. Frank H. Kaufert presented the report of the Publications Committee as follows:

This committee consists of:

F. H. Kaufert, Chairman
E. A. Behr
John B. Grantham
Frederick H. Vogel

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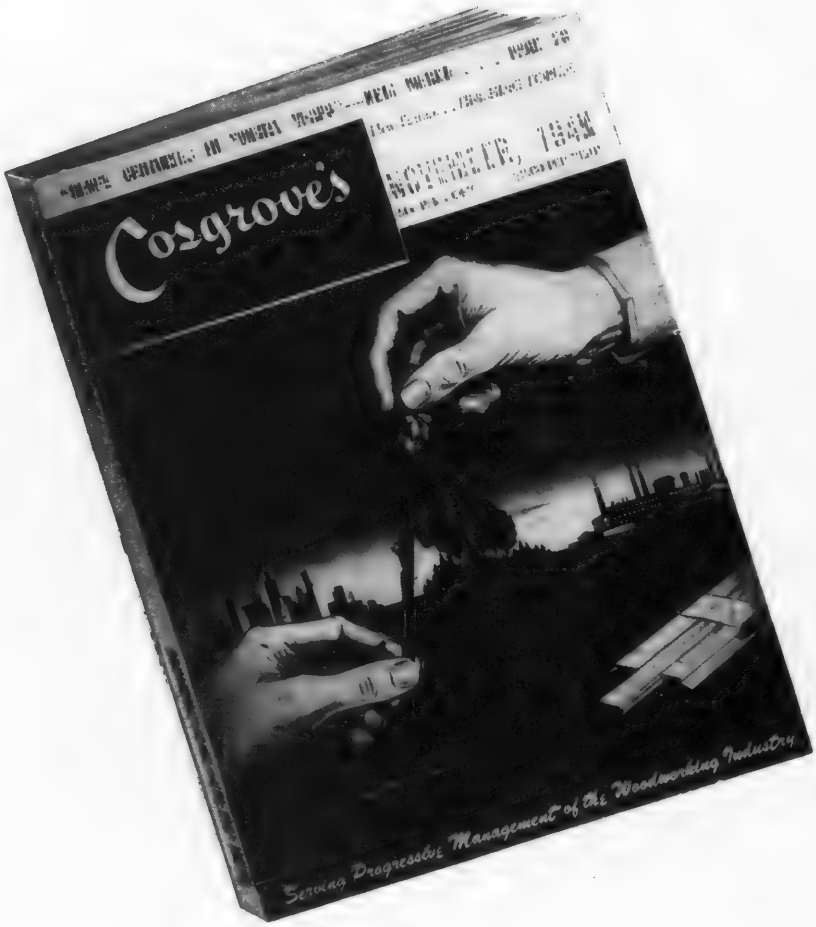

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During the interval since the first national meeting of the Society the Publications Committee has engaged in the following activities:

1. The Style Standards have been revised and prepared for publication. They are presented on pages 246–256 of the first volume of our Proceedings and separates are available from the Secretary–Treasurer on request. Their use as a guide by members presenting papers at future meetings will greatly simplify the job of editing prior to publication. Also, the Publications Committee requests the comments and suggestions of all members on the Style Standards in aiding in improving them.
2. The manuscripts presented at the first meeting were reviewed prior to preparation of the Proceedings. The excellent job of editing done by your program chairman, Dean G. A. Garratt, made this a rather simple undertaking and we wish to take this opportunity to thank both him and President Fred Gottschalk for what amounted to more than just assistance.

Our plans for the next period call for review and editing of the papers presented at this meeting and an attempt to prepare a list of abbreviations for titles, organizations, etc. The latter list is urgently needed by the Secretary–Treasurer for use in the preparation of membership lists.

On motion duly made and seconded the report was accepted.

Chicago Meeting Committee

Mr. Charles H. White, Chairman of the Chicago Meeting Committee reported the following:

Twenty-eight Table Top Exhibits in operation.

Advance registration	466
Attendance to date	355
Expected at Banquet	251

The Ladies Program has been successfully carried out. On proper motion and second, approval of this report was voted.

Secretary–Treasurer's Report

The Secretary–Treasurer reported the membership enrollment to date as 1261 consisting of 64 supporting members and 1197 in the grades of voting and associate. He reported further that total receipts of the Society from the beginning of operations up to March 15 was about $27,000. Actual expenditures plus known outstanding obligations totaled approximately the same figure. He stated further that the Society has some 1500 bound copies of Volume I Proceedings available for sale after supplying the membership. Also, that renewal dues will be coming in soon.

Pacific Northwest Section

Mr. A. C. Knauss, Chairman of the Pacific Northwest Section reported that this group, consisting of about 200 members, had been formed by the adoption of Associated Forest Products Technologists, a group that had been formed in the coast regions of Washington and Oregon and was in operation before the FPRS was satrted. He requested that the Society publish the dates for meetings of this section.

Northeast Region

Mr. James F. Hamilton reported an initial meeting of members in the Northeast Region on February 27 at Hotel Pennsylvania in New York City. Attendance at a business meeting was 47: 178 registered and 137 attended the luncheon. Dues of $1.00 per member per year were established.

Midwest Section

Mr. Edward T. Bailey reported an initial meeting of the newly formed Midwest Section in Chicago on February 27 with an attendance of 67.

Student Membership

Prseident Gottschalk referred again to the new grade of student membership. Whether or not to continue this grade is to be considered by the Executive Board after it has been in operation for a year.

Business From the Floor

Mr. Walter Buehler read a resolution that had been presented to the Directors of American Wood Preservers Association and of

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Has Never Failed

SOUTHERN PINE ASSOCIATION
NEW ORLEANS, LA.

THE *Newman 8-B*
PLANER, MATCHER AND MOLDER

This modern, precision built machine
has been especially designed for all-purpose work in small and medium sized mills and factories. It planes 22 inches wide and 8 inches thick, joints 4 inches thick and will match 14 inches wide. Frame is heavy and rigid. Four 6" diameter feed rolls driven by heavy chains and machine cut sprockets give speeds of 30, 50 and 75 feet per minute. Combination heads are standard equipment on the NEWMAN 8-B.

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Newman Machine Co., Inc.
Greensboro, N. C., U. S. A.

Engineered wood products

are solving wood industry problems with finished wood parts, laminated wood, and special wood products.

Gamble Brothers

are leaders
in this development . . .
since 1900

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American Railway Engineering Association by the Wood Preservation Committees of these associations. This resolution protested against the sale under the Marshall Plan of untreated railroad cross-ties to European countries. The relation of the FPRS to this resolution and the action it should take and the effect on U. S. railroad and treating plants was discussed by Messrs. James F. Hamilton, Bror Grondal, E. T. Bailey, F. H. Vogel, C. A. Rishell, Alan I. Barr, P. R. Hicks and Jac. Tigelaar. A motion made by Professor Grondal and duly seconded that a committee be appointed to consider this matter and to report its recommendations to the Executive Committee was, on a vote by raised hands, lost.

On a request by President Gottschalk for suggestions for subjects of future meetings and for places for meeting; Mr. Ed R. Linn requested that a session be devoted to the utilization of poorly formed and defective hardwood trees.

Election of Officers

President Gottschalk presented the results of the ballots that had been reviewed by a committee of tellers headed by Mr. Dwight Bensend showing elections as follows:

President

GEORGE A. GARRATT, Dean,
School of Forestry,
Yale University,
New Haven, Connecticut

1st Vice President

EDWARD G. LOCKE, Chemical Engineer,
Pacific Northwest Forest & Range Experiment Station,
U. S. Forest Service,
Portland, Oregon

2nd Vice President

JOHN H. GIVIDEN, Executive Vice-President,*
Dunbar Furniture Company,
Berne, Indiana

Regional Board Member—Northwest Region

R. D. PAULEY, Manager,
Development Department
Weyerhaeuser Timber Company,
Longview, Washington

Regional Board Member—Northeast Region

ROY M. CARTER, Utilization Technologist,
United States Forest Service,
Philadelphia, Pennsylvania

The President announced that in accordance with the Bylaws the new officers would be installed at 11:30 A. M. on the last day of the meeting.

Adjournment

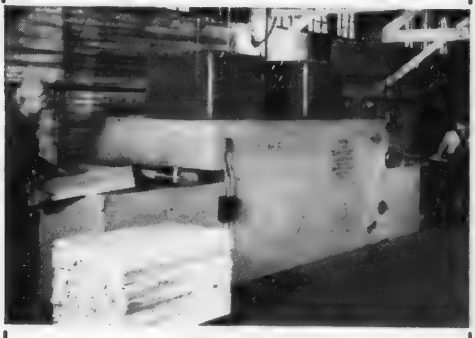
Meeting adjourned at 6:00 P. M.

Following adjournment the members and guests assembled at the Paul Bunyan Cocktail Table and the Loggers' Cook Shack. Decorations to the Cook Shack tables included Paul Bunyan pictures in color contributed by The Mead Sales Company.

* Subsequent to his election Mr. Gividen resigned because of pressing business commitments and the Executive Board, acting in accordance with the By-Laws, appointed Mr. James F. Hamilton, Technical Director, Perkins Glue Company, Lansdale, Pennsylvania, to fill the position of 2nd Vice President.

So-o—you're going to put in some high frequency heating equipment!

We're building more and more *Thermex units for more and more Thermex users. Fully developed Thermex apparatus, far beyond the experimental stage, is produced on the assembly line basis to meet demand. Here being built is Thermex Model 10H, a sectional unit becoming increasingly popular for lumber edge-bonding and other wood-glue jobs.



Continuous lumber edge-bonding machine with Thermex Model 10H mounted in sections, on top. The sections can be arranged and rearranged to fit virtually any wood-glue production system using high frequency heat. What's your wood-glue job? Thermex apparatus can eliminate holding time, save fixtures, floor space, manpower, adhesive.

HERE'S HOW TO PICK IT

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2 **Choose the high frequency heating equipment that's backed by a record of actual, practical use in the wood-glue field.**

You guessed it. THERMEX rates aces high on both counts.

THERMEX pioneered in high frequency heating apparatus for industry at large and wood-glue work in particular. Every THERMEX installation embodies the benefits of unexcelled application "know-how".

Claims regarding THERMEX efficiency and dependability are based upon many successful *installations*, for lumber edge-bonding, laminating, fabricating.

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HIGH FREQUENCY HEATING APPARATUS FOR EDGE-BONDING, LAMINATING, FABRICATING

*T. M. Reg. U. S. Pat. Off.

INSTALLATION OF OFFICERS

New officers elected by ballot (see page 332), together with Mr. James F. Hamilton, who had been appointed by the Executive Board as Second Vice-President following the resignation of Mr. John H. Givideu who was elected to that office, were introduced at 11:30, March 24 to the members and guests, by President Gottschalk. They were:

President ---------- GEORGE A. GARRATT

First Vice-President ---------- EDWARD G. LOCKE

Second Vice-President ---------- JAMES F. HAMILTON

Regional Board Member, Northeast ---------- ROY M. CARTER

ROBERT D. PAULEY, who had been elected *Regional Board Member, Pacific Northwest Region,* was unable because of urgent prior engagements to be present.

Mr. Gottschalk reported that the office of Secretary–Treasurer, an appointive position, was filled by the re-appointment of Mr. T. R. C. Wilson*.

The newly elected President and First and Second Vice-Presidents are to serve until the close of the 1949 annual meeting and the two regional board members till the end of the 1951 meeting.

Other members of the Executive Board who will serve during the coming year are:

North-Central Region ---------- JAC. H. TIGELAAR

South-Central Region ---------- KENNETH G. CHESLEY

Southeast Region ---------- CARL A. RISHELL

Southwest Region ---------- ROBERT A. COCKRELL

Past President ---------- FRED W. GOTTSCHALK

*Effective June 1 Mr. Charles E. Van Hagan was appointed by the Executive Board to the office of Secretary–Treasurer as successor to Mr. Wilson who had requested to be relieved from duty.

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★ AIRPLANE PARTS ★ PIANO STOCK
★ MILL WORK ★ LADDER STOCK
★ BEVEL SIDING ★ KILN DRYING

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Phone GR. 0294–0295
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BRUNSWICK, GEORGIA

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Domestic and
Central American
Woods

STIMSON
LUMBER COMPANY

Loggers and Lumber
Manufacturers

Old Growth Yellow Fir

FOREST GROVE, OREGON

AUDIT REPORT

May 19, 1948

Dr. George A. Garratt, President
Forest Products Research Society

Dear Dr. Garratt: We have examined the accounts of the Forest Products Research Society for the period January 1, 1947 to March 31, 1948. In our opinion, the accompanying balance sheet and operating statement set forth the financial condition of the Society on March 31, 1948 and the results of its operations for the 15 months period ended on that date.

Respectfully submitted,

(Signed) L. J. MARKWARDT

(Signed) V. C. HOBART

BALANCE SHEET

March 31, 1948

Assets			
Cash		$ 4,799.25	
Accounts Receivable (Advertising, etc.)		1,899.35	
Inventory:—			
Equipment	$ 185.05		
Publications on hand	4,590.00		
Postage	150.00	4,925.05	
Total			$11,623.65
Liabilities and Net Worth			
Accounts Payable		4,939.56	
Accrued Salaries		24.70	
Prepaid dues for fiscal year ending March 31, 1949		6,761.50	
		11,725.76	
Deficit		102.11	
Total			$11,623.65

OPERATING STATEMENT

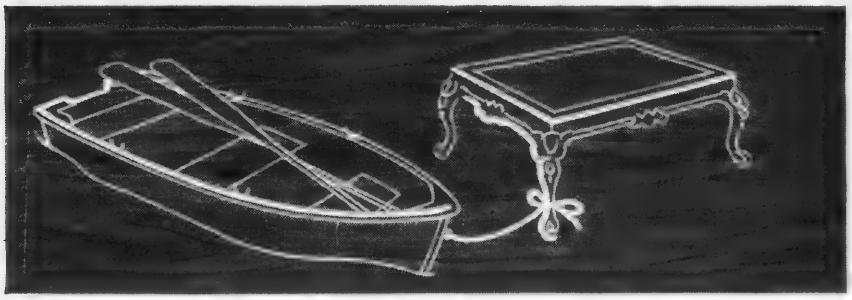
January 1, 1947–March 31, 1948

Receipts			
Membership Dues:—			
Associate and Voting	$12,111.50		
Supporting	6,550.00		
Student	51.00	$18,712.50	
Contributions		480.00	
Publications		494.60	
Advertising		9,010.00	
Meetings (Oct.–Nov. 1947)	1,432.55		
(March 1948)	2,287.19	3,719.74	
Total			$32,486.61
Expenditures			
Salaries		2,051.44	
Office Expense:—			
Stenographic	2,472.18		
Postage, telephone and telegraph	3,151.78		
Stationery and Printing	4,185.19		
Equipment	164.35		
Miscellaneous	239.62	10,213.12	
Publications:—			
Preprints and Reprints	1,025.59		
Proceedings	8,353.80	9,379.39	
Subscriptions to Wood Magazine		1,022.00	
Travel		100.00	
Meetings (Oct.–Nov. 1947)	2,305.03		
(March 1948)	2,616.38	4,921.41	
Total			27,687.36
Balance on hand March 31, 1948			$ 4,799.25

TABLE-TOP EXHIBITS

Displays were set up in the Exhibit Room, adjacent to the Furniture Club, by producers of forest products, suppliers of equipment, or material used by the forest products industries, consumers of wood, laboratories in the wood field, etc. These were open for the entire period of the meeting. The purpose of the table-top display is to provide information for those concerned with forest products development, production or utilization. The facilities for the space was made available through the courtesy of Colonel Lawrence H. Whiting, President, and Mr. Frank S. Whiting, Vice-President, of the American Furniture Mart. The exhibitors were:

American Lumber & Treating Co.
Casein Company of America
DeLux Saw & Tool Co.
The Dow Chemical Company
Elmendorf Corporation
Forman, Ford and Company
B. F. Goodrich Chemical Company
Greenlee Machine Co.
Hart Moisture Gauges, Inc.
Haskelite Manufacturing Corp.
Hyster Company
Mattison Machine Co.
Moore Dry Kiln Co.
Muskegon Machine Co.
Onsrud Machine Works
Perkins Glue Company
Pluswood Incorporated
Power Nails Co.
Standard Dry Kiln Company
Timber Engineering Company
U. S. Forest Products Laboratory
Westinghouse Electric Corporation
Williams Patent Crusher & Pulverizer Co.
Wisconsin Knife Works
WOOD
Woodwelding Inc.
Wood Working Digest
Yale University



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P-398 Plyophen—Produces hard or softwood plywood or veneers of utmost water resistance with maximum speed at minimum temperature and pressure.

No. 6000 Plyophen—Produces a bond resistant to boiling and practically all solvents. Cures at temperatures as low as 75° F.

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Zurich, Switzerland • Milan, Italy • Buenos Aires, Argentina

SYNTHETIC RESINS • CHEMICAL COLORS • PHENOLIC PLASTICS • INDUSTRIAL CHEMICALS

Attendance List

National Annual Meeting, 1948

CHICAGO, ILLINOIS
MARCH 22, 23, AND 24

NORTHEAST REGION

CONNECTICUT

Bethel
S. F. McLaren, Snyder Chemical Corp.
F. H. Snyder, Snyder Chemical Corp.

New Haven
G. A. Garratt, Yale School of Forestry
N. V. Poletika, Yale School of Forestry

MAINE

Farmington
R. W. Mitchell, Maine Skewer & Dowel
D. F. Pierce, Maine Skewer & Dowel

Orono
Gregory Baker, University of Maine
F. K. Beyer, University of Maine

MASSACHUSETTS

Belmont
G. W. Kuehn, American Creosoting Co.

Boston
R. E. Ferdinand, Joslin Showcase Fixture Co.

Chicopee
J. N. Tynan, A. G. Spalding & Sons

Foxboro
R. N. Perkins, Foxboro Co.

Montreal
L. L. Brown, Dominion Tar & Chem. Co.

NEW HAMPSHIRE

Durham
Joseph Seiberlich, University of N. H.

Manchester
P. F. Brusquini, Hermsdorf Fixture Mfg. Co.
H. L. Grass, Hermsdorf Fixture Mfg. Co.
H. A. Hermsdorf, Hermsdorf Fixture Mfg. Co.

NEW JERSEY

Berlin
W. D. Eisenhauer, American Structural Products Co.

Bloomfield
Leonard Repsher, Bakelite Corp.

Jersey City
T. J. Reese, Boliden Mining Co., % Leonard J. Buck, Inc.

Moorestown
T. D. Perry, Consultant

Ridgewood
W. B. Wilkins, Consulting Engineer
Rudolph Willard, Snyder & Willard

NEW YORK

Bainbridge
L. E. Clark, Jr., Casein Co. of America

Little Falls
C. B. Lundstrom, Lundstrom Laboratories, Inc.

Lockport
G. P. Harris, Monsanto Chemical Co.
Alan Marra, Monsanto Chemical Co.

Newburgh
O. M. Johnson, Muskegon Machine Co.

New Rochelle
C. B. Hemming, U. S. Plywood Corp.

New York City
B. A. Anderton, Barrett Division, Allied Chemical & Dye
R. J. Bandekow, Casein Co. of America
R. J. Barbour, Bakelite Corp.
A. I. Barr, The Barrett Division
T. H. Friedlin, N. Y. C. RR
R. G. Goodwin, Paper & Industrial Appliances
C. C. Kuehn, Georgia Forest Products
David Lesser, Self
Richard Lischer, Morgan Furniture
A. Lobert, Hart Moisture Gauges & Kaydel Corporation
Uno Lowgren, American Defibrator, Inc.
V. C. Otley, The Barrett Division, Allied Chemical & Dye Corp.
J. L. Rodgers, Bakelite Corp.
H. H. St. Clair, Hart Moisture Gauges, Inc. & Kaydel Corporation
H. B. Sanders, Casein Co. of America

Niagara Falls
J. W. Ripple, Jr., The Carborundum Co.
W. K. Van Ormer, Carborundum Co.

Rochester
H. L. Charles, Stromberg Carlson Co.

Syracuse
A. H. Bishop, New York State College of Forestry
R. J. Hoyle, N. Y. State College of Forestry
Lawrence Leney, N. Y. State College of Forestry

Troy
W. M. Langdon
J. M. Yavorsky, W. T. LaRose & Assoc.

ONTARIO

Burlington
A. S. Nicholson, A. S. Nicholson & Son, Ltd.

Ottawa
J. H. Jenkins, Forest Products Laboratories of Canada
D. G. Miller, Forest Products Laboratories of Canada
H. Schwartz, Forest Products Laboratories of Canada
I. W. Smith, University of Toronto

PENNSYLVANIA

Avondale
R. L. Krause, Du Pont Co.

Downingtown
R. T. DePan, Downingtown Mfg. Co.

Erie
D. T. Jackson, Hammermill Paper Co.

Kreamer, Snyder Co.
M. O. Wolbach, Wood-Metal Industries

Lancaster
A. J. McMurray, DeWalt, Inc.

Lansdale
J. F. Hamilton, Perkins Glue Co.

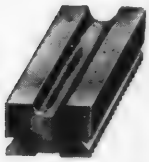
Philadelphia
R. M. Carter, Northeastern Forest Experiment Station, U. S. Forest Service
R. P. Hopkins, Resinous Products & Chemical Company

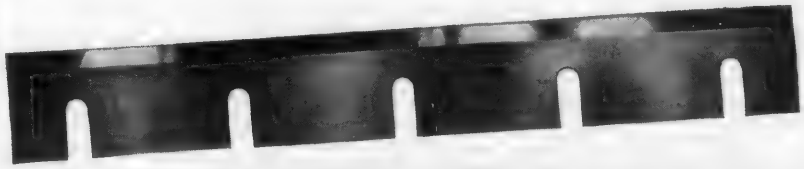
Pittsburgh
G. A. Wagner, Koppers Co., Inc., Tar Products Div.

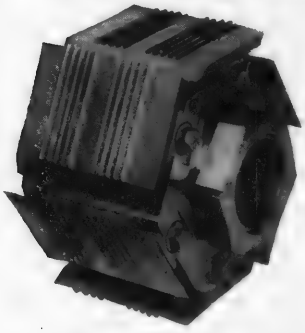
Sewickley
C. W. Farrier, Gunnison Homes, Inc.

QUEBEC

Gatineau
John Huberman, International Plywoods, Ltd.







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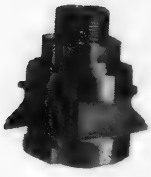

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FOREST PRODUCTS RESEARCH SOCIETY

SOUTHEAST REGION

DELAWARE

Wilmington
A. A. Pavlic, E. I. du Pont de Nemours

DISTRICT OF COLUMBIA

Washington
Rear Admiral Paul F. Lee, U. S. Navy
H. B. McKean, Timber Engineering Co.
J. C. Moore, National Paint Varnish & Lacquer Association
G. J. Olson, Forest Products Division, U. S. Dept. of Commerce
C. A. Rishel, National Lumber Mfrs. Association
H. G. Uhl, Timber Engineering Co.
Douglas Worf, Navy Dept.

FLORIDA

Gainesville
Walter Buehler, University of Florida

Jacksonville
R. H. Knight, Moore Dry Kiln Co.

MARYLAND

Catonsville
R. M. Baker, Westinghouse

NORTH CAROLINA

Asheboro
W. W. Bulla

Asheville
John Boring, Morgan Mfg. Co., Inc.
Kurt Burgold, Morgan Furniture Co.
R. A. Hertzler, Southeastern Forest Exp. Sta.

Canton
R. J. Sprang, Champion Paper & Fibre Co.

Goldsboro
W. B. Griffing, A. T. Griffing Mfg. Co.

High Point
R. I. Quigley, The Lilly Co.

Black Mountain
A. P. Bullard, Morgan Mfg. Co., Inc.
R. K. Morgan, Morgan Mfg. Co., Inc.
C. T. Sobal, Morgan Furniture Co.

Wilmington
G. Colucci, Southern Box & Lumber Co.

VIRGINIA

Altavista
R. H. Sides, The Lane Co., Inc.

Blacksburg
E. G. Stern, Virginia Polytechnic Institute

Portsmouth
M. M. Kirk, Monsanto Chemical Co.

Salem
E. S. Johnson, Consultant

WEST VIRGINIA

Morgantown
George Marra, West Virginia University
O. B. Starkey, W. Va. Wood Products Corp.

NORTH CENTRAL REGION

ILLINOIS

Chicago
V. S. Acton, Westinghouse Electric Co.
Russell H. Albin, Glue Jobber
Henry J. Allison, Jr., Container Corp. of America
H. W. Angel, American Lumber & Treating Co.
D. W. Anstett, Powernail Company
E. P. Anstett, Powernails Company
R. C. Art, Wood Magazine
W. T. Austin, Plywood
R. F. Babcock, Jr., Masonite Corporation
Ned Bailey, Wood Working Digest
Wilmer J. Balster, Don L. Quinn Company
G. A. Barclay, Southern Lumberman
Ralph Barker, Student
Gustave Barshefsky, The Elmendorf Corporation
Arthur C. Bartz, Onsrud Machine Works
F. M. Beegle, General Chemical Company
E. A. Behr, Chapman Chemical Co.
C. H. Beiger, Sears-Roebuck & Co.
C. J. Berrigan, E. I. Du Pont de Nemours
John W. Biba, Simonds Saw & Steel Co.
Johan A. Bjorksten, Bjorksten Research Labs.
D. E. Black, Acme Steel Company
R. H. Bliss, Abana Products
Clarence J. Blocher, Frank Miller & Sons, Inc.
Edward J. Boarini, Certain-Teed Products Corp.
Ralph A. Bond, Ralph A. Bond & Associates
A. B. Bonneville, Interlake Chemical Corporation
H. A. Brennan, Lawyer
Gunther Carlberg, Central Wooden Box Assoc.
Alfred S. Cieslak, Elmendorf Corp.
R. R. Clegg, American Lbr. & Treating Co.
J. J. Connelly, The Foxboro Company
T. J. Connelly, Dean Company
J. H. Conover, U. S. Gypsum Company
Carl R. Cook, Sears-Roebuck & Co.
A. E. Counter, Barker Chemical Company
Donald M. Crooks, Douglas Fir Plywood Assn.
P. L. Dafoe, Acme Steel Company
Captain T. M. Davis, Quartermaster Food and Container Institute for the Armed Forces
P. D. Dean, The Dean Co.
H. Draper, Home Outfitters, Inc.
Robson B. Dunwody, Celotex Corp.
Hugh Eames, Retailer of Home Furnishings
Norbert J. Eggert, Hartmann-Sanders Co.
Arthur Leonard Ellis, The Lehon Company
Armin Elmendorf, The Elmendorf Corp.
N. W. Elmer, Vern E. Alden Co.
Judson D. Elston, General Box Co.
Arthur L. Fader, A. L. Fader & Co.
P. R. Farlow, Illinois Central Ry. Co.
Al Feldmann, Deluxe Saw & Tool Co.
John Flynn, Mattison-Greenlee Service Corp.
John M. Frey, Girdler Corp.
A. E. Gabriel, Armour Research Foundation
Gabriel E. Galos, Commonwealth Edison Co.
Henry Garnjobst, Jr., Wood Magazine
R. J. Garvey, Peter Cooper Corp.
C. W. Gault, Hercules Powder Co.
Stanley Thomas Ginsberg, Dearborn Company
C. Goodman, Deluxe Saw & Tool Co.
Fred W. Gottschalk, American Lbr. & Treating Co.
G. W. Grace, Peter Cooper Corp.
Burdett Green, American Walnut Mfrs. Assn.
A. R. Gronki, National Door Mfrs. Assn.
A. V. Grundy, Q. M. Food & Container Corp.
F. P. Guignon, Monsanto Chemical Co.
W. A. Gullicksen, Churchill Cabinet Co.
Gordon F. Hagemann, Sears-Roebuck & Co. (Norwood Mfg. Co.)
Paul C. Hamann, Chicago & Northwestern Ry.
C. B. Hicks, Popular Mechanics Magazine
P. R. Hicks, Service Bureau, American Wood Preservers Assn.
John S. Horn, Interlake Chemical Corp.
V. F. Hribar, American Lbr. & Treating Co.
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Otto R. Jagd, Chemist, Sherwin-Williams Company
L. C. Johnson, Mattison-Greenlee Service Corp.
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R. A. Kay, Western Electric Company
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Laurence P. Keith, National Lumber Mfrs. Assn.
Richard L. Kenyon, Chemical & Engineering News
J. W. Kendrick, Met-L-Wood Corporation
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Ray Klass, The Pacific Lumber Co.
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Wayne C. Leckey, Popular Mechanics Magazine
Harry J. Lindeman, H. J. Lindeman & Co.

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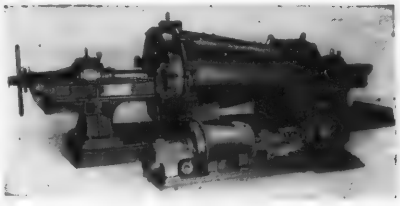

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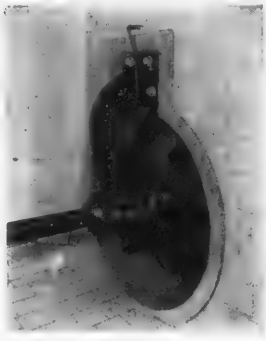

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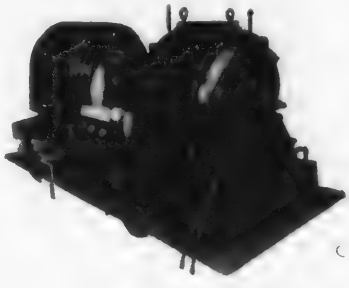

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ALLIED CHEMICAL & DYE CORPORATION

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Incorporated August 8, 1947 under the articles of the General Not for Profit Corporation Act in the State of Illinois.

Incorporators of said corporation are:

Fred W. Gottschalk
George A. Garratt
William J. Baker

Registered Office is Room 2034, 332 South Michigan Avenue, Chicago 4, Illinois, and the Registered Agent is Fred W. Gottschalk.

The first Executive Board shall be:

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George A. Garratt
William J. Baker
Bror L. Grondal
Edward G. Locke
James F. Hamilton
Jac. H. Tigelaar
Robert A. Cockrell
Carl A. Rishell
Kenneth G. Chesley

ARTICLES OF ASSOCIATION

ARTICLE I

Name

The name of the Society shall be FOREST PRODUCTS RESEARCH SOCIETY.

ARTICLE II

Objects and Purposes

SECTION 1. The objects and purposes of this Society shall be (1) to facilitate the interchange of information among individuals and organizations who are interested in forest products research, development, or utilization (a) by abstracting papers, reports, and other publications, (b) by publishing and distributing pertinent information, (c) by encouraging cooperation among interested persons, (d) by promoting standard test methods and procedures, (e) by sponsoring meetings for the presentation and discussion of reports of investigations and experiences of its members and others, for the interchange of ideas, and for the broadening of acquaintanceships among individuals interested in forest products research, development, or utilization; and (2) in general to encourage and promote the efficient utilization of wood and other forest products.

SECTION 2. The Society shall be operated on a non-profit basis.

BYLAWS

of the

FOREST PRODUCTS RESEARCH SOCIETY

ARTICLE I

Members

SECTION 1. CLASSES OF MEMBERS. The Society shall consist of Voting Members, Supporting Members, and Associate Members; the qualifications shall be as follows:

A Voting Member shall be any individual who is actively engaged in planning, supervising, or working in any phase of forest products research, development, or utilization. Voting Members shall have all rights and privileges of the Society.

A Supporting Member shall be any organization or individual who financially assists the Society by paying dues in accordance with Article II, Section 1, of these bylaws. Each Supporting Member who is an individual shall have all rights and privileges of a Voting Member. Each organization that is a Supporting Member may designate one representative who shall have all rights and privileges of a Voting Member.

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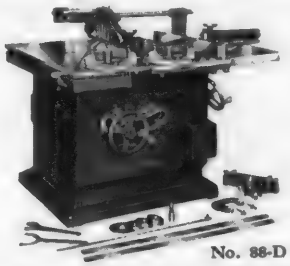

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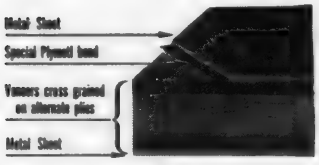

*PLYMETL — Light gauge sheets of steel or aluminum and other metals are bonded to one or both faces of a plywood plaque. Widely used for Diesel locomotive side panels, escalator panels, table tops, truck trailer side panels, delivery truck bodies, railway passenger car interiors, bakery proof boxes, air conditioning equipment, etc.

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Canada: Railway & Power Engineering Corp., Ltd.

An Associate Member shall be any individual who is interested in forest products research, development, or utilization, although not actively engaged in such pursuits. Associate Members shall have all rights and privileges of Voting Members, except those of holding office and voting.

SECTION 2. ELECTION OF MEMBERS. Members shall be elected by action of the Executive Board. An affirmative vote of two-thirds of the directors shall be required for election.

SECTION 3. VOTING RIGHTS. Each Voting Member and the designated representative of each Supporting Member shall be entitled to one vote on each matter submitted to a vote of the members.

SECTION 4. TERMINATION OF MEMBERSHIP. The Executive Board by affirmative vote of two-thirds of all of the members of the Board may suspend or expel a member for cause after an appropriate hearing, and may, by a majority vote of those present at any regularly constituted meeting, terminate the membership of any member who becomes ineligible for membership, or suspend or expel any member who shall be in default in the payment of dues for the period fixed in Article II, Section 3 of these bylaws.

SECTION 5. RESIGNATION. Any member may resign by filing a written resignation with the secretary-treasurer, but such resignation shall not relieve the member so resigning of the obligation to pay any dues theretofore accrued and unpaid.

SECTION 6. REINSTATEMENT. Upon written request signed by a former member and filed with the secretary-treasurer, the Executive Board may by the affirmative vote of two-thirds of the members of the Board reinstate such former member to membership upon such terms as the Board may deem appropriate.

SECTION 7. TRANSFER OF MEMBERSHIP. Membership in this Society is not transferable or assignable.

ARTICLE II

Dues

SECTION 1. FISCAL YEAR DUES. The fiscal year shall begin on April 1 and shall terminate on March 31 of each year. The annual dues, payable during the first two (2) months of the fiscal year, shall be as follows: Voting Members, Ten Dollars ($10.00); Supporting Members, One Hundred Dollars ($100.00); and Associate Members, Ten Dollars ($10.00).

SECTION 2. APPLICATION FOR ADMISSION. An applicant for admission to the Society shall indicate the desired class of membership on the application blank. For applicants who are elected to membership on or after April 1 and prior to January 1, the full amount of the annual dues shall be collected for and applied to the fiscal year in which they are elected. For applicants who are elected to membership on or after January 1 and prior to April 1, the annual dues collected shall apply to the whole of the next fiscal year as well as to the balance of the fiscal year in which they are elected, but publications of the fiscal year of election are not included in the benefits of membership. Dues submitted with application blanks shall be returned to applicants who are not elected to the Society.

SECTION 3. UNPAID DUES. Any member whose dues are unpaid on July 1 shall not receive publications or releases of the Society, and, if the member's dues are in arrears on March 31, the membership shall be cancelled, except as provided for in Section 4 of this Article.

SECTION 4. EXTENSION. The Executive Board by a majority vote may extend the time for payment of the dues of any Voting Member who is unable to pay them within the prescribed time.

ARTICLE III

Executive Officers

SECTION 1. EXECUTIVE OFFICERS. The executive officers shall be the president, vice-presidents, last past-president, and a secretary-treasurer.

SECTION 2. PRESIDENTS. The president and first and second vice-presidents shall be elected at each Annual Meeting.

SECTION 3. SECRETARY-TREASURER. The secretary-treasurer shall be appointed by the Executive Board and bonded at the expense of the Society. The secretary-treasurer shall have no vote on the Executive Board.

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. . . fence posts, culvert bridges, farm buildings.

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. . . roofing, cooling towers, wood pipe, decking and general factory construction.

For Utilities and Railroads . . .
. . . poles, posts, cross ties, platform and car lumber.

For the Homeowner . . .
. . . window sash, sills, joists, siding, sleepers, steps and fences.

Where wood is subject to attack by termites and decay use PENTAchlorophenol —a *modern* wood preservative.

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SECTION 4. DUAL OFFICES. One person can hold only one office at any given time.

SECTION 5. OTHER EXECUTIVE OFFICERS. The Executive Board may elect or appoint such other offices, including one or more assistant secretaries and one or more assistant treasurers, as it shall deem desirable, such officers to have authority and perform the duties prescribed, from time to time, by the Executive Board.

SECTION 6. ELECTION AND TERM OF OFFICE. The elective executive officers of the Society shall be elected by the Voting Members and designated representative of Supporting Members at the regular Annual Meeting. If the election of officers shall not be held at such meeting, such election shall be held as soon thereafter as convenient. Vacancies may be filled or new offices created and filled at any meeting of the Executive Board. Each officer shall hold office until his successor shall have been duly elected and shall have qualified.

SECTION 7. VACANCY IN PRESIDENT'S OFFICE. In the event of a vacancy in the office of president, the unexpired term of this office shall be completed by the first vice-president.

SECTION 8. PRESIDENT. The president shall be the principal executive officer of the Society and shall in general supervise and control all of the business and affairs of the Society. He shall preside at all meetings of the members and of the Executive Board. He may sign, with the secretary-treasurer or any other proper officer of the Society authorized by the Executive Board, any deeds, mortgages, bonds, contracts, or other instruments, which the Executive Board has authorized to be executed, except in cases where the signing and execution thereof shall be expressly delegated by the Executive Board or by these bylaws or by statute to some other officer or agent of the Society; and in general shall perform all duties incident to the office of president and such other duties as may be prescribed by the Executive Board from time to time.

SECTION 9. VICE-PRESIDENTS. In the absence of the president or in the event of his inability or refusal to act, the first vice-president shall perform the duties of the president, and when so acting, shall have all the powers of and be subject to all the restrictions upon the president. Any vice-president shall perform such other duties as from time to time may be assigned to him by the president or by the Executive Board.

SECTION 10. SECRETARY-TREASURER. The secretary-treasurer shall give a bond for the faithful discharge of his duties in such sum and with such surety or sureties as the Executive Board shall determine. He shall have charge and custody of and be responsible for all funds and securities of the Society; receive and give receipts for moneys due and payable to the Society from any source whatsoever, and deposit all such moneys in the name of the Society in such banks, trust companies or other depositaries as shall be selected in accordance with the provisions of Article VIII of these bylaws; and in general perform all the duties incident to the office of secretary-treasurer and such other duties as from time to time may be assigned to him by the president or by the Executive Board.

This officer shall keep the minutes of the meetings of the members and of the Executive Board in one or more books provided for that purpose; see that all notices are duly given in accordance with the provisions of these bylaws or as required by law; be custodian of the corporate records and of the seal of the Society and see that the seal of the Society is affixed to all documents, the execution of which on behalf of the Society under its seal is duly authorized in accordance with the provisions of these bylaws; keep a register of the post office address of each member as furnished by such member; and in general perform all duties incident to the office of secretary-treasurer and such other duties as from time to time may be assigned to him by the president or by the Executive Board.

SECTION 11. ASSISTANT TREASURERS AND ASSISTANT SECRETARIES. If required by the Executive Board, the assistant treasurers shall give bonds for the faithful discharge of their duties in such sums and with such surety or sureties as the Executive Board shall determine. The assistant treasurers and assistant secretaries, in general, shall perform such duties as shall be assigned to them by the treasurer or by the secretary or by the president or the Executive Board.

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ARTICLE IV

Regional Board

SECTION 1. REGIONAL BOARD. A regional board to assist with the management of the Society, consisting of six officers, shall be elected at Annual Meetings as outlined by this Article.

SECTION 2. DESIGNATION OF REGIONS. The regions shall be as follows:

Northwest Region:

Alaska, Idaho, Montana, Oregon, Washington and adjacent Canada.

Northeast Region:

Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont and adjacent Canada.

North Central Region:

Illinois, Indiana, Iowa, Michigan, Minnesota, Nebraska, North Dakota, Ohio, South Dakota, Wisconsin and adjacent Canada.

Southwest Region:

Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming.

Southeast Region:

Delaware, District of Columbia, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, and West Virginia.

South Central Region:

Alabama, Arkansas, Kansas, Kentucky, Louisiana, Mississippi, Missouri, Oklahoma, Tennessee, and Texas.

SECTION 3. ELECTION AND TERM OF OFFICE. The terms of regional board members shall begin at the close of the Annual Meeting at which they are elected by the Voting Members and the designated representatives of the Supporting Members of that region, and shall continue through the next three (3) Annual Meetings. Each of the Regions designated in Section 2 shall be represented by one (1) Executive Board Member; with elections to be held on three (3) year intervals as shown in Article V, Section 16.

SECTION 4. MEMBERS OUTSIDE OF UNITED STATES AND CANADA. Voting Members and the designated representative of Supporting Members not residing in a designated region shall not qualify to vote for regional board members.

ARTICLE V

Executive Board

SECTION 1. BOARD OF DIRECTORS. The Board of Directors, hereafter designated the Executive Board, shall manage the affairs of the Society.

SECTION 2. MEMBERSHIP OF EXECUTIVE BOARD. The Executive Board shall consist of the president, vice-presidents, last past-president, and the six regional board members.

SECTION 3. MANAGEMENT. The Executive Board shall manage the affairs of the Society and shall have full power to control and regulate all matters not provided for in these bylaws. It shall act on applications for membership; make appropriations for specific purposes; direct the care of surplus funds of the Society; audit the accounts of the secretary-treasurer; and publish the reports and Proceedings of the Society.

SECTION 4. QUORUM. Five (5) members of the Executive Board shall constitute a quorum for the transaction of business at any meeting of the Board, provided, that if less than a majority of the directors are present at said meeting, a majority of the directors present may adjourn the meeting from time to time without further notice.

SECTION 5. MANNER OF ACTING. The act of a majority of the directors present at a meeting at which a quorum is present shall be the act of the Executive Board, except where otherwise provided by law or by these bylaws.

SECTION 6. VACANCIES. Any vacancy occurring in the Executive Board or any directorship to be filled by reason of an increase in the number of directors, shall be filled by the Executive Board. A director elected to fill a vacancy shall be elected for the unexpired term of his predecessor in office.

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Actual tests show labor costs are reduced with the NELSON POLE SHAVER. One example: Where 20 men peeled a specified number of poles by old methods, 4 men now do the same number of poles in less time, thereby saving the cost of 16 men—and obtaining superior shaved poles!
A 30-foot Class 6 pole can be shaved in one minute and smaller or larger poles will vary according to size.

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Completely Shaves Every Pole—
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SECTION 7. NOTICE. Notice of any special meeting of the Executive Board shall be given at least ten (10) days previously thereto by written notice delivered personally or sent by mail or telegram to each director at his address as shown by the records of the corporation. If mailed, such notice shall be deemed to be delivered when deposited in the United States mail in a sealed envelope so addressed, with postage thereon prepaid. If notice be given by telegram, such notice shall be deemed to be delivered when the telegram is delivered to the telegraph company. Any director may waive notice of any meeting. The attendance of a director at any meeting shall constitute a waiver of notice of such meeting, except where a director attends a meeting for the express purpose of objecting to the transaction of any business because the meeting is not lawfully called or convened. Neither the business to be transacted at, nor the purpose of, any regular or special meeting of the board need be specified in the notice or waiver of notice of such meeting, unless specifically required by law or by these bylaws.

SECTION 8. EMERGENCY ACTION. In the event of emergency, the president can act upon matters of management by mail or telegraph with members of the Executive Board. Questions must be submitted so that a board member may vote as affirmative, negative, or not-voting. Receipt of five (5) affirmative replies shall constitute a quorum. A report of each such vote shall be transmitted, within a reasonable period of time, to each member of the Executive Board.

SECTION 9. REGULAR MEETINGS. A regular annual meeting of the Executive Board shall be held without other notice than this bylaw, immediately after, and at the same place as, the annual meeting of members. The Executive Board may provide by resolution the time and place, either within or without the State of Illinois, for the holding of additional regular meetings of the Board without other notice than such resolution.

SECTION 10. SPECIAL MEETINGS. Special meetings of the Executive Board may be called by or at the request of the president or any two board members. The person or persons authorized to call special meetings of the board may fix any place, either within or without the State of Illinois, as the place for holding any special meeting of the Board called by them.

SECTION 11. PUBLICATIONS. Subject to the action of the Society, the Executive Board may withhold from publication, in whole or in part, discussions, papers, or reports, the propriety or soundness of which is considered questionable.

SECTION 12. VACANCY IN ELECTIVE OFFICE. A vacancy in any elective office, other than that of president, shall be filled by an appointee of the Executive Board. Such an appointee shall not serve beyond the next Annual Meeting unless then elected to fill the remainder of an unexpired term.

SECTION 13. RE-ELECTION. The president, vice -presidents, and regional executive board members shall be ineligible for re-election to the *same* office within three (3) years after the expirations of their respective terms.

SECTION 14. REMOVAL. Any officer or agent elected or appointed by the Executive Board may be removed by the Executive Board whenever in its judgement the best interests of the Society would be served thereby, but such removal shall be without prejudice to the contract rights, if any, of the person so removed.

SECTION 15. COMPENSATION. Executive Board members, as such, shall not receive any stated salaries for their services, but by resolution of the Executive Board, a fixed sum and expenses of attendance, if any, may be allowed for attendance at each regular or special meeting of the Board; provided, that nothing herein contained shall be construed to preclude any director from serving the Society in any other capacity and receiving compensation therefor.

SECTION 16. TERMS OF INITIAL ELECTIVE OFFICERS. The terms of the first or initial elective officers shall terminate at the close of Annual Meetings as follows:

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Treating Plant Equipment

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** Sales Agents For: WYANDOTTE CHEMICALS CORP. Wyandotte, Michigan Naxtane

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ROCHESTER, N. Y. 532 So. Clinton St. (7) STone 1282

Office	*Year*
President	1948
Vice-President	1948
Past-Chairman	1948
Northwest Regional Board Member	1948
Northeast Regional Board Member	1948
North-Central Regional Board Member	1949
Southwest Regional Board Member	1949
Southeast Regional Board Member	1950
South-Central Regional Board Member	1950

ARTICLE VI

Meeting of Members

SECTION 1. ANNUAL MEETING. An annual meeting of the members shall be held on one or more succesive days during the month of March in each year, beginning with the year 1948 for the purpose of electing such executive officers and members of the regional board as are then to be elected and for the transaction of such other business as may come before the meeting. The president, vice-presidents, and two (2) regional board members shall be elected at each Annual Meeting.

SECTION 2. SPECIAL MEETING. Special meetings of the members may be called either by the president, the executive board, or not less than one-tenth of the members having voting rights.

SECTION 3. PLACE OF MEETING. The Executive Board may designate any place, either within or without the State of Illinois, as the place of meeting for any annual meeting or for any special meeting called by the Executive Board.

SECTION 4. NOTICE OF MEETINGS. Written or printed notice stating the place, day and hour of any meeting of members shall be delivered, either personally or by mail, to each member entitled to vote at such meeting, not less than five nor more than forty days before the date of such meeting, by or at the direction of the president, or the secretary-treasurer, or the officers or persons calling the meeting. In case of a special meeting or when required by statute or by these bylaws, the purpose for which the meeting is called shall be stated in the notice. If mailed, the notice of a meeting shall be deemed delivered when deposited in the United States mail addressed to the member at his address as it appears on the records of the Society, with postage thereon prepaid.

SECTION 5. QUORUM. Fifteen (15) Voting Members, or the designated representatives of Supporting Members, present at any meeting shall constitute a quorum. If a quorum is not present at any meeting of members, a majority of the members present may adjourn the meeting from time to time without further notice.

SECTION 6. ORDER OF BUSINESS. The order of business at meetings of the Society shall be arranged by the Executive Board, subject to additions or changes by the votes of a majority of the Voting Members and the designated representatives of Supporting Members present and voting.

SECTION 7. NOMINATIONS. The National Nominating Committee shall nominate at least one (1) eligible member for each elective office to be filled by vote of the Society as a whole at the next Annual Meeting. Each regional nominating committee shall nominate at least one (1) eligible member for the office of Regional Executive Board member for that Region as defined in Article IV, Section 2 of these bylaws, and shall report its nominees to the National Nominating Committee not later than January 15. The list of nominees for all elective offices shall be sent, by the National Nominating Committee, to the secretary-treasurer not later than February 1, and any vacancies in the list of nominees shall be filled in by the Executive Board before the ballot is sent to the Voting Members. Written consent shall be obtained from each nominee before the nominee's name is placed on the ballot.

SECTION 8. NOMINATING COMMITTEES. At each Annual Meeting, the presiding officer shall appoint (1) a National Nominating Committee consisting of six (6) Voting Members, who are not officers, and (2) a Regional Nominating Committee consisting of five (5) Voting Members, who are not members of the Executive Board, from each region for which a Regional Board Member is to be elected at the succeeding annual meeting.

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SECTION 9. VOTING. Voting shall not be restricted to the names presented by the Nominating Committees. Any fifty (50) Voting Members or designated representative of Supporting Members may file with the secretary-treasurer not later than January 15 the name of a candidate for any elective office for which they are entitled to vote, and the name of such candidate shall be placed on the ballot. Furthermore, any Voting Member may insert on the ballot the name of an eligible nominee of his own choice for any elective office for which he is entitled to vote.

SECTION 10. BALLOTS. The voting membership in each Region shall elect its Executive Board member, and the ballot shall clearly indicate the nominees for whom the members in the respective Regions are entitled to vote. The ballot must contain the names of all nominees for each office, arranged alphabetically and followed by a line on which the voter may write the name of an eligible nominee of his own choice. The ballot, with envelopes for secret voting, shall be placed in the mails to each Member entitled to vote not earlier than forty-five (45) days before the Annual Meeting and not later than twenty (20) days before the Annual Meeting.

SECTION 11. SEALED BALLOTS. Ballots shall be sealed and sent or delivered to the secretary-treasurer before the polls close prior to which time a voter may withdraw or replace his ballot. The envelope shall be signed by the voter who shall also type or letter thereon his name and his address as listed on the Society records.

SECTION 12. POLLS. The polls shall be closed at noon of the first day of the Annual Meeting, and the ballots shall be counted by five (5) Members of any grade appointed as tellers by the presiding officer at the Annual Meeting.

SECTION 13. ELECTION. The persons who receive the highest number of votes for the offices for which they were candidates shall be declared elected, providing that no one person may be elected to more than one office. In the event of a tie between candidates for the same office, announcement of the fact shall be made to the assembly immediately, and the Voting Members present at the closing session of the Annual Meeting shall elect the officer from the candidates so tied. The presiding officer shall announce to the Meeting the names of the officers so elected.

ARTICLE VII

Committees

SECTION 1. COMMITTEES OF THE EXECUTIVE BOARD. The Executive Board, by resolution adopted by a majority of the directors in office, may designate one or more committees, each of which shall consist of two or more directors, which committees, to the extent provided in said resolution, shall have and exercise the authority of the Executive Board in the management of the Society; but the designation of such committees and the delegation thereto of authority shall not operate to relieve the Executive Board, or any individual director, of any responsibility imposed upon it or him by law.

SECTION 2. OTHER COMMITTEES. Other committees not having and exercising the authority of the Executive Board in the management of the Society may be designated by a resolution adopted by a majority of the directors present at a meeting at which a quorum is present. Except as otherwise provided in such resolution, members of each such committee shall be members of the Society, and the Executive Board of the Society shall appoint the members thereof. Any member thereof may be removed by the person or persons authorized to appoint such member whenever in their judgment the best interests of the Society shall be served by such removal.

SECTION 3. TERM OF OFFICE. Each member of a committee shall continue as such until the next annual meeting of the members of the Society and until his successor is appointed, unless the committee shall be sooner terminated, or unless such member be removed from such committee, or unless such member shall cease to qualify as a member thereof.

SECTION 4. CHAIRMAN. One member of each committee shall be named chairman by the president of the Society. No chairman shall serve continuously for a term in excess of three (3) years.

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- ROOF TRUSSES
- LAMINATED ARCHES
- LAMINATED BEAMS
- LUMBER FABRICATORS
- ENGINEERING IN WOOD

SECTION 5. VACANCIES. Vacancies in the membership of any committee may be filled by appointments made in the same manner as provided in the case of the original appointments.

SECTION 6. QUORUM. Unless otherwise provided in the resolution of the Executive Board designating a committee, a majority of the whole committee shall constitute a quorum and the act of a majority of the members present at a meeting at which a quorum is present shall be the act of the committee.

SECTION 7. RULES. Each committee may adopt rules for its own government not inconsistent with these bylaws or with rules adopted by the Executive Board.

ARTICLE VIII

Society Sections

SECTION 1. SECTIONS. Sections of the Society may be authorized by the Executive Board upon written petition of ten (10) or more Voting Members residing in a geographic area small enough to justify the belief that an effective local organization may be established. Section members shall be members of the Society. A Section must hold at least one meeting each year in order to retain its authorization.

SECTION 2. SECTION OFFICERS. Each Section shall have at least a chairman and a secretary as officers who shall keep the Executive Board informed of Section activities. The Section secretary shall transmit one copy of each paper delivered at Section meetings to the Executive Board for consideration of its suitability for publication by the Society. Submission of papers to the Executive Board does not preclude their publication elsewhere, either prior to or subsequent to the Section meetings at which they are presented.

SECTION 3. SECTION BYLAWS. Any Section may, subject to the approval of the Executive Board, adopt for its own government such bylaws as may be necessary, provided that no part of these bylaws shall conflict with the Articles of Association, Bylaws, or the policies of the Society.

SECTION 4. SECTION DUES. Sections may assess nominal dues in addition to the Society dues; and, if a Section desires, the secretary-treasurer of the Society will collect Section dues at the same time that Society dues are payable, such Section dues to be forwarded to the Section.

SECTION 5. SECTION MEMBERSHIP. Every member of the Society in good standing is automatically entitled to membership in that Section in which he establishes his domicile, but such affiliation is not mandatory. The domicile of a member shall be his home or residence, unless his place of business and his professional affiliations lie within the territory of another Section, in which event he may, by declaration, establish his domicile with said other Section for the purpose of Section membership. The domicile of a member, as so indicated, shall determine the Region in which he is entitled to cast his vote for a Regional Executive Board Member.

SECTION 6. SECTION TERMINATION. The Executive Board shall have the right at any time to revoke the authorization of any Section and to terminate its existence. A Section whose authorization has been revoked by the Executive Board shall have the right to appeal its case to the Society.

ARTICLE IX

Contracts, Checks, Deposits and Funds

SECTION 1. CONTRACTS. The Executive Board may authorize any officer or officers, agent or agents of the Society, in addition to the officers so authorized by these bylaws, to enter into any contract or execute and deliver any instrument in the name of and on behalf of the Society and such authority may be general or confined to specific instances.

SECTION 2. CHECKS, DRAFTS, ETC. All checks, drafts or other orders for the payment of money, notes or other evidences of indebtedness issued in the name of the Society, shall be signed by such officer or officers, agent or agents of the Society and in such manner as shall from time to time be determined by resolution of the Executive Board. In the absence

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of such determination by the Executive Board, such instruments shall be signed by the treasurer or an assistant treasurer and countersigned by the president or a vice-president of the Society.

SECTION 3. DEPOSITS. All funds of the Society shall be deposited from time to time to the credit of the Society in such banks, trust companies or other depositaries as the Executive Board may select.

SECTION 4. GIFTS. The Executive Board may accept on behalf of the Society any contribution, gift, bequest or devise for the general purposes or for any special purpose of the Society.

ARTICLE X

Certificates of Membership

SECTION 1. CERTIFICATES OF MEMBERSHIP. The Executive Board may provide for the issuance of certificates evidencing membership in the Society which shall be in such form as may be determined by the Board. Such certificates shall be signed by the president or a vice-president and by the secretary-treasurer or an assistant secretary-treasurer and shall be sealed with the seal of the Society. All certificates evidencing membership of any class shall be consecutively numbered. The name and address of each member and the date of issuance of the certificate shall be entered on the records of the Society. If any certificate shall become lost, mutilated or destroyed a new certificate may be issued therefor upon such terms and conditions as the Executive Board may determine.

SECTION 2. ISSUANCE OF CERTIFICATES. When a member has been elected to membership and has paid any initiation fee and dues that may then be required, a certificate of membership shall be issued in his name and delivered to him by the secretary-treasurer, if the Executive Board shall have provided for the issuance of certificates of membership under the provisions of Section 1 of this Article.

ARTICLE XI

Books and Records

The Society shall keep correct and complete books and records of account and shall also keep minutes of the proceedings of its members, Executive Board and committees having any of the authority of the Executive Board, and shall keep at the registered or principal office a record giving the names and addresses of the members entitled to vote. All books and records of the Society may be inspected by any member, or his agent or attorney for any proper purpose at any reasonable time.

ARTICLE XII

Fiscal Year

The fiscal year of the Society shall begin on the first day of April in each year and end on the last day of March in the following year.

ARTICLE XIII

Purposes

The purposes of the corporation are stated in the ARTICLES OF ASSOCIATION.

The corporation, known as the Society, also has such powers as are now or may hereafter be granted by the General Not For Profit Corporation Act of the State of Illinois.

ARTICLE XIV

Offices

The Society shall have and continuously maintain in the State of Illinois a registered office and a registered agent whose office is identical with such registered office, and may have other offices within or without the State of Illinois as the Executive Board may from time to time determine. The address of the Registered Office is Room 2034, 332 South Michigan Avenue, Chicago 4, Illinois, and address of the Society headquarters is Box 2010, University Station, Madison 5, Wisconsin.

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St. Louis, Mo.

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ARTICLE XV

Seal

The Executive Board shall provide a corporate seal which shall be in the form of a circle and shall have inscribed thereon the name of the Society and the words "Corporate Seal, Illinois."

ARTICLE XVI

Waiver of Notice

Whenever any notice whatever is required to be given under the provisions of the General Not For Profit Corporation Act of Illinois or under the provisions of the articles of incorporation or the bylaws of the Society, a waiver thereof in writing signed by the person or persons entitled to such notice, whether before or after the time stated therein, shall be deemed equivalent to the giving of such notice.

ARTICLE XVII

Amendments to Bylaws

SECTION 1. ALTERING BYLAWS. These bylaws may be altered, amended, or repealed or new bylaws may be adopted by a majority of the Executive Board present at any regular meeting or at any special meeting, provided that at least ten days' written notice is given of intention to alter, amend or repeal or to adopt new bylaws at such meeting,

SECTION 2. PROPOSED AMENDMENTS. Proposed amendments to these bylaws, must be offered in writing, signed by at least five (5) Voting Members, and forwarded to the secretary-treasurer not less than sixty (60) days prior to the Annual Meeting. They shall be published with the notices for the meeting.

SECTION 3. BALLOT ON AMENDMENTS. Proposed amendments shall be in order for discussion at the Annual Meeting, and may be amended or approved if two-thirds of the votes of the Voting Members present and voting are affirmative. Such amendments shall then be submitted by letter ballot to the entire Voting Membership and shall be adopted if approved by a majority of the votes cast.

ARTICLE XVIII

Parliamentary law

The latest edition of Robert's Rules of Order shall be followed in all meetings of the Society on points of procedure that are not specifically covered by these bylaws.

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STYLE STANDARDS FOR FOREST PRODUCTS RESEARCH SOCIETY PAPERS 1947-1948

The Forest Products Research Society was founded as an organization to cover the fields of research, development, production, and utilization of forest products. The Society has as its objectives the following: facilitating the publication and interchange of information, encouraging cooperation, providing test methods and procedures, abstracting results, and, in general, encouraging and promoting the efficient utilization of wood and other forest products.

The Society solicits and encourages the preparation of papers by members and nonmembers for presentation and discussion at meetings and for publication. To qualify for Society sponsorship, papers must not only present suitable subject matter but must be well written and should conform to recognized style standards. The purpose of this style manual is to aid authors in meeting these requirements and to acquaint them with rules of the Society relating to the preparation and submission of manuscripts and accompanying illustrations. It is hoped that the necessity for conformance to certain rules or standards is recognized by everyone and that this Style Standard will serve as a guide and encourage the preparation and presentation of papers. Suggestions for the presentation of papers before meetings of the Society are included.

For those members of the Society well versed in the principles of good technical writing and presentation of papers, this style standard will contain little that is new because it follows rather closely similar standards of other societies. But, for those who are less experienced in writing and presentation of papers, it is hoped that this style manual will serve as a guide and contain helpful suggestions.

General

It is well to remember that the chief purpose of a paper is to convey information to others, many of whom are less familiar with the general subject than the author. This usually is accomplished most effectively through use of simple terms and expressions, by conciseness, and by omission of highly technical terms and phraseology except where the nature of the subject matter makes such terms unavoidable.

Papers should be kept as short as possible and as a general rule the text material should not exceed 4,000 words or about 14 double-spaced typewritten pages. Long quotations should be avoided by referring to source material. Illustrations and tables are desirable but they should be reduced to the minimum necessary to present and illustrate the results properly.

The desired order of the contents of papers is: (a) TITLE (b) Authors' name, business connection, and mailing address (c) Abstract (d) Body of paper (e) Appendixes (f) Bibliography (g) Tables (h) Captions for illustrations and (i) Illustrations, including graphs, charts, diagrams, sketches, and line drawings.

Copies of Manuscript

Two copies, an original and first carbon, are required for each paper or report submitted to the Society. Text matter must be typewritten, double spaced, on white paper; blue prints and "ditto" material are not satisfactory. Photographs or drawings should also be in duplicate, clearly identified. Photostats or copies may be used for the first carbon but not in the original.

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Titles of papers should be definite in meaning and as short as possible. The author's name, title, affiliation, with city and state (territory or province) should appear immediately following the title, for example:

STRENGTH TESTS FOR DOUGLAS FIR

John J. Doe
Technical Director,
Rae Lumber Co.
Rae, California

Abstract

A short abstract (50 to 100 words) should be included on the first page immediately preceding the introductory paragraph and following the author's name and affiliation. The purpose of the abstract is to give the reader an indication of the paper's contents and it should be prepared with this purpose in mind.

Page Numbers

Number each page in the manuscript consecutively, including table and illustration pages, and appendix. Start the numbering with the first page of text (do not number the foreword or table of contents pages, or frontispiece illustrations). Put the number at the bottom of the page. If you wish to insert a page in a manuscript, give it the number of the preceding page, followed by an alphabetical letter, as follows: —1A—.

Tables

In general, long or detailed tables are not satisfactory to the reader or the printer. Usually, the summary or average figures are sufficient; too much tabular material may preclude printing by the Society. Tables should be numbered consecutively and should be referred to in the text as Table 1, 2, 3, etc. Tables of not more than six lines may be included in the text, but larger tables should be typed on separate sheets.

Graphs and Drawings

One or two clear graphs are often more usable to the reader than many tables. Cross section paper with faint lines or more than ten spaces to the inch will not provide a usable reproduction (see remarks on photographs and drawings).

Graphs, line drawings and sketches should be drawn with black ink on heavy white paper or tracing cloth. Blue prints and photostatic prints are not suitable.

Drawings for reproduction must be of good draftsmanship and of a size and weight of line so that they can be reduced to the width of a column or a page. Preferably, the drawings should be exactly four times as large as the size required for the finished cut, and the capital letters on the inked drawing should be 0.25 in. high. Use black india ink, medium weight lines and uniform letters; fine lines, figures close to lines, and pencil shading will not reproduce.

Photographs

Photographs must be clear, detailed prints (preferably glossy) in a size of 5 by 7 in. or 8 by 10 in. Blurred, dark, or half-tone copies cannot be used. The presentation may be improved by one or two good pictures, but they should be held to an absolute minimum and definitely related to important features of the text.

Photographs should not be mounted or pasted in the manuscript. Paper clips will mar photographs and should not be used unless photographs have wide margins. Fasten the photograph to sheets by making slits in the page or by means of corner markings.

The main title of the photograph, drawing or graph will be set in type by the printer and should be firmly attached to the illustration. The proper figure number and the author's name marked lightly on the back and margin of prints often is helpful in identifying material. However, such identification should be made with a pen and blue ink. Also, ball-point pens should not be used because they may mar the photograph.

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Lettering

There are several important points that must be observed in connection with lettering on graphs, drawings and other illustrative material. With few exceptions lettering done with lettering guides is superior to freehand lettering and should be used wherever possible. Since most illustrative material is greatly reduced in size on publication, letters must be of sufficient size and lines heavy enough to reproduce.

Headings and Numbering

Headings and subheadings should appear throughout the text to divide the subject matter into logical parts and to emphasize the major elements and considerations.

Tables, other than brief tabulations appearing as part of the text, should be numbered consecutively throughout the paper, including appendixes, if any, using arabic numerals.

All illustrations, including graphs, charts, diagrams, sketches, line drawings, and photographs, should also be numbered consecutively throughout the paper, including appendixes, if any, using arabic numerals. All such illustrations are properly referred to as "figures."

Footnotes

Footnotes are used to make minor explanations of material in the text. They are also used for literature references (see Literature Citations).

Footnote references are numbered consecutively from beginning to end of the manuscript. (Tables are footnoted separately). Two footnote references occurring in the same place are separated by a space ([3] [4]).

The footnote itself should preferably be typed immediately following the line in which the footnote reference is placed and should always be kept on the same page with its reference.

Numerals

Do not begin a sentence with numerals.

Whole numbers through ten; spell out (unless used in sequence with larger numerals).

Fractions and numbers greater than ten; use numerals.

Identification numbers; as Fig. 1, page 6, etc. use numerals.

Units of measure; as 6 ft., 2 gal., etc. use numerals.

Ciphers are required before the decimal point in quantities that are less than 1.0; 0.55 lb. retention. In case readings are carried out to several places (example: 1.100) the ciphers should be included.

Express percentages and precise figures as decimals; 3.5 percent, not 3½ percent.

Numbers following numbers, as forty 4-in. timbers; spell first, numerals for second.

Series of numbers of more than four figures in the text, point off; as 1,234,567, but space in tabular matter 1 234 567.

Capitals

Use capitals sparingly; it is not good practice to use them for emphasis in technical writing. Capitalize principal words in headings and titles. Capitals are used for: Vol. 26, Table III, test No. 1, specimen A, the North region, Committee on Wood Preservation, Lake Erie, President John Doe, the North and South Railroad, or Douglas fir. Use lower case for: north or northern (merely denoting direction); the committee recommends; John Doe, president; portland cement; diesel engine, southern pine; and western hemlock.

Compound Words

The only simple rule that can be given regarding the use of hyphenated words is: two or more words used as a unit modifier are hyphenated. Examples:

wood-using industries	10-year growth
old-age trees	½-acre plots
two 16-foot sawlogs	three-fourths inch
air-seasoned lumber	two 16-foot sawlogs

Hyphens are used not only to join words, but to keep the components separated for ease of reading (A-frame, man-hours) and to prevent misunderstanding (co-op, re-treat).

Society or Association Names

Refer to the Forest Products Research Society as the Society or the FPRS. When mentioning other groups spell out the name in full when the first reference is made, then use the initials, as follows: ACS, ASTM, ASME, SAF, etc.

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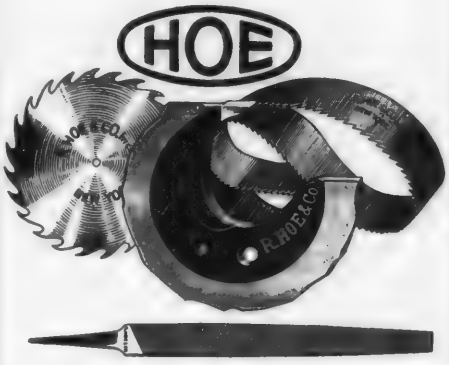

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Abbreviations

Do not abbreviate terms that are infrequently used. Abbreviate common units of measure only when used with numerals denoting a definite quantity (except in tabular material), for example: 40 bd. ft. were selected; and several board feet of lumber were added.

Plural expressions should be abbreviated in the singular, thus: 2 in., not 2 ins., nor two inches. Express dimensions as 2 by 4 in., not 2 in. x 4 in.

The use of chemical symbols, in general, should be kept to a minimum, except in tables and methods of analysis; however, common names when first used should be followed by the chemical formula to insure identification. Correct abbreviations for scientific and technical terms and for standard lumber terms are as follows:

SCIENTIFIC AND TECHNICAL TERMS

Absolute	abs.
Alternating current	a.c.
(as adjective)	a-c.
American wire gage	A.w.g.
Ampere	amp.
Ampere-hour	amp-hr.
Angstrom unit	A
Average	av.
Barrel	bbl.
Birmingham wire gage	B.w.g.
Brake horsepower	b.hp.
British thermal unit	Btu.
Brown and Sharpe (gage)	B.&S.
Bushel	bu.
Calorie	cal.
Centigrade	C.
Centigram	cg.
Centiliter	cl.
Centimeter	cm.
Cents	spell out
Chemically pure	c.p.
Circular mils	cir. mils
Cubic	cu.
Cubic centimeter (volume)	cu. cm.
Day	spell out
Decigram	dg.
Deciliter	dl.
Decimeter	dm.
Degree or degrees	deg.
Diameter	diam.
Direct current	d.c.
(as adjective)	d-c.
Electric horsepower	e. hp.
Electomotive force	emf.
Equation	Eq.
Fahrenheit	F.
Figure, Figures	Fig., Figs.
Foot or feet	ft.
Foot-pound	ft-lb.
Gallon or gallons	gal.
Gallons per minute	gpm.
Grain	spell out
Gram or grams	g.
Horsepower	hp.
Horsepower-hour	hp-hr.
Hour or hours	hr.
Hydrogen ion concentration	pH
Inch or inches	in.
Inch-pound	in-lb.
Indicated horsepower	i.hp.
Kilocycle	kc.
Kilogram	kg.
Kilogram-calorie	kg-cal.
Kilogram-meter	kg-m.
Kiloliter	kl.
Kilometer	km.
Kilovolt	kv.
Kilovolt-ampere	kva.
Kilovolt peak	kv.p.
Kilowatt	kw.
Kilowatt-hour	kw-hr.
Less than carload	l.c.l.
Linear	lin.
Liter	l.
Logarithm (common)	log
Magnetomotive force	mmf.
Maximum	max.
Meter	m.
Meter-kilogram	m-kg.
Microfarad	μf
Micro-microfarad	μ μf
Micromicron	μ μ
Micron	μ
Mile	spell out
Miles per hour	mph.
Milliampere	ma.
Milligram	mg.
Millihenry	mh.
Milliliter	ml.
Millimeter	mm.
Millimicron	m μ
Millivolt	mv.
Minimum	min.
Minute or minutes	min.
Month	spell out
Number	No.
Ohm	spell out
Ounce	oz.
Parts per million	ppm.
Per	spell out
Percent	spell out
Per centum	per cent
Pint	pt.
Pound or pounds	lb.
Pound-foot	lb-ft.
Pound-inch	lb-in.
Pounds per square foot	lb. per sq.ft.
Pounds per square inch	psi.
Quart	qt.
Radius	rad.

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SCIENTIFIC AND TECHNICAL TERMS—Continued

Revolutions per minute	rpm.
Root mean square	rms.
Second or seconds	sec.
Specific gravity	sp.gr.
Square	sq.
Tensile strength	tens.str.
Ton	spell out
United States (gage)	U.S.
Volt	spell out
Volume, Volumes	Vol., Vols.
Watt	spell out
Watt-hour	w-hr.
Week or weeks	spell out
Yard or yards	yd.
Year or years	yr.

STANDARD LUMBER TERMS

Air-dried	AD
Board	bd.
Board foot	bd.ft.
Board (foot) measure	b.m.
Better	Btr.
Clear	Clr.
Center matched	CM
Common	Com.
Cubic foot	cu.ft.
Dressed and center matched	D&CM
Dressed and matched	D&M
Dressed two sides and matched	D2S&M
Dimension	Dim.
Edge grain	E.G.
End matched	EM
First and seconds (hardwood grades)	FAS
Flat grain	F.G.
Flooring	Flg.
Feet board measure	feet b.m.
Hardwood	hdwd.
Heart	Hrt.
Heartwood	Hrtwd.
Kiln-dried	KD
Knocked down	k.d.
Lumber	lbr.
Length	lgth.
Linear foot	lin.ft.
Log run	LR
Thousand	M.
Thousand (feet) board measure	M.b.m.
Merchantable	Merch.
Mill run	MR.
Thousand (feet) surface measure	M.s.m.
Plain, as plain sawed	Pln.
Quartered—referring to hardwoods	Qtd.
Random	rdm.
Random lengths	r.l.
Round	rnd.
Random widths	r.w.
Surfaced 1 side and 1 edge	S&E
Surfaced one edge	S1E.
Surfaced two edges	S2E.
Surfaced one side	S1S.
Surfaced two sides	S2S
Surfaced 2 sides and 1 edge	S2S1E
Surfaced four sides	S4S
Sapwood	Sap.
Select	Sel.
Softwood	Sftwd.
Sound	snd.
Square	sq.
Square edge and sound	Sq. E. & S.
Squares	sqrs.
Standard	Std.
Tongued and grooved	T&G
Timbers	Tbrs.
Thickness	4/4, 6/4, etc. = 1 inch, 1½ inches, etc.
Vertical grain	V. G.
Width	Wth.
Weight	wt.

The use of symbols such as % for percent, ° for degree, ′ for feet or minutes, ″ for inches or seconds, should only be used in complex tabular data. The symbol # should not be used for any purpose. The abbreviation ml. for milliliter to indicate a measure of capacity is preferable to cc.

Common Names

The common names of species of wood should be the ones in general use in the industry, and, to avoid the possibility of confusion, the scientific name should appear in italics after the common name the first time it is used in the paper.

Literature Citation

Reference to literature the author has consulted can be made in two ways: (1) as a list at the end of the manuscript; or (2) as footnotes. A list of Literature Cited should contain at least seven references. (If you have less than seven, use them as footnotes.).

EXAMPLES:

Books:

Sargent, Charles Sprague. 1905. Manual of the trees of North America. Ed. 2, 818 pp., illus. Boston and New York.

Periodicals:

Simmons, Fred C. 1945. Methods of loading lumber at the rear of small sawmills. Canada Lumberman 65 (23): 39–40, illus.

Bratton, Allen W. and R. H. Ferguson. 1945. Use of the spray gun in marking timber. Jour. Forestry 43: 113–117.

INTERLAKE
PRODUCTS FROM COAL
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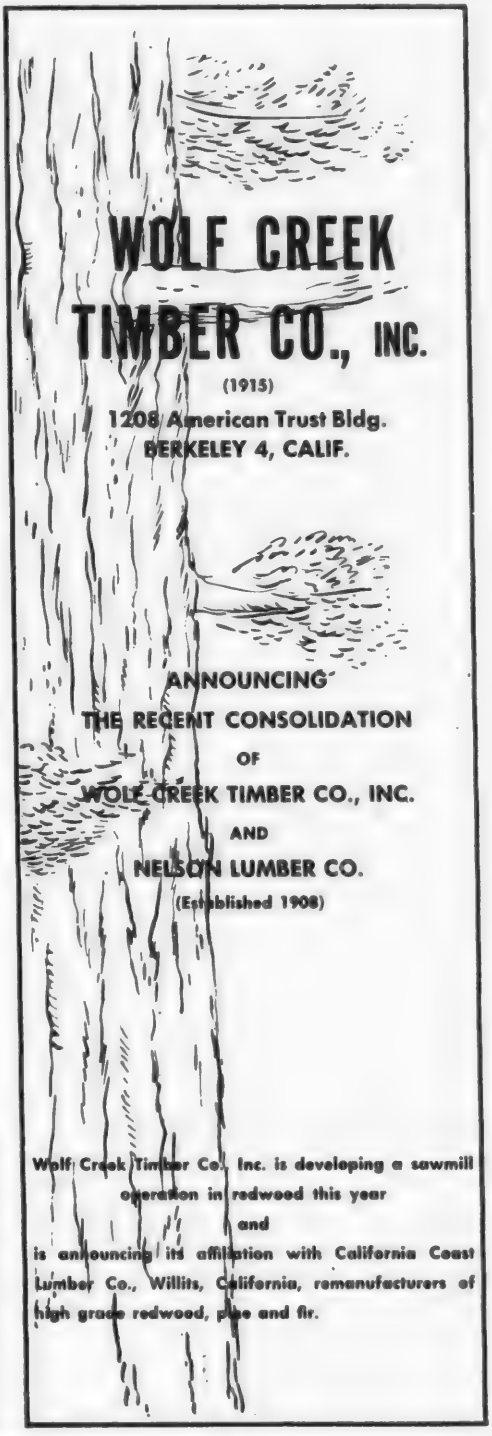

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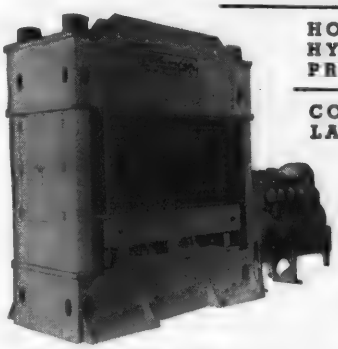

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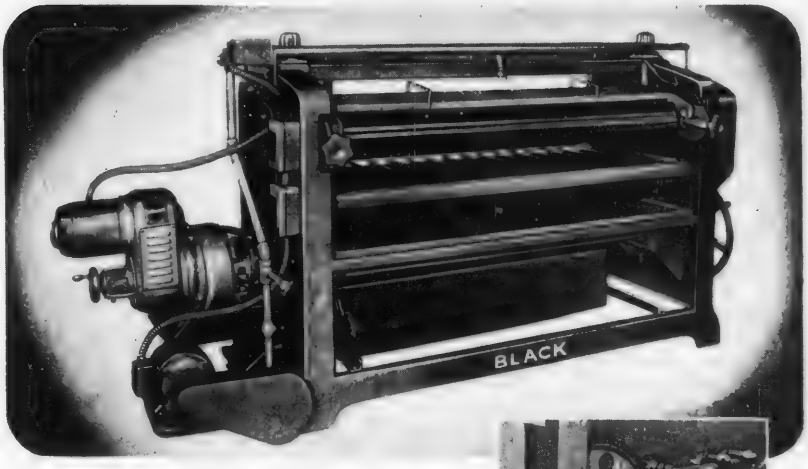

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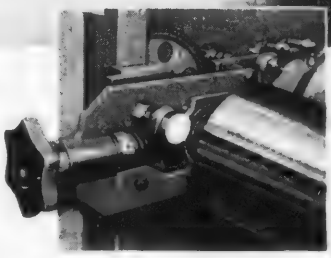

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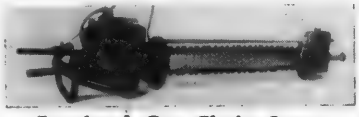

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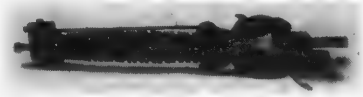

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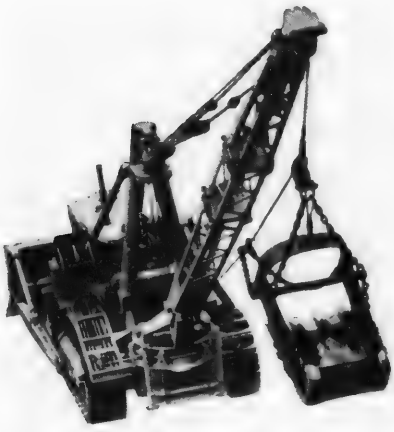

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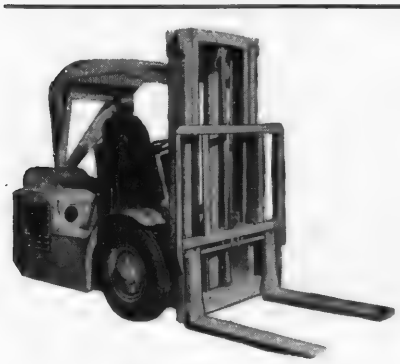

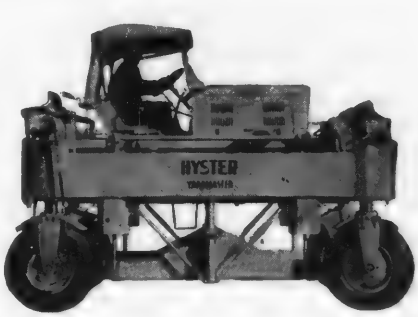

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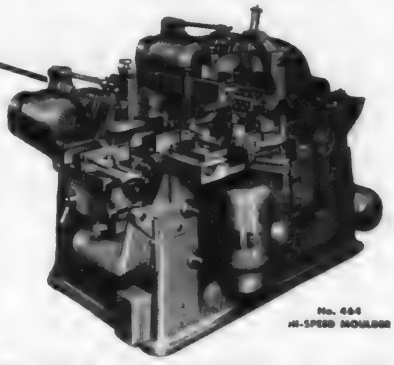

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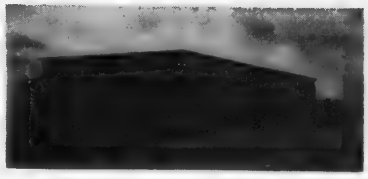

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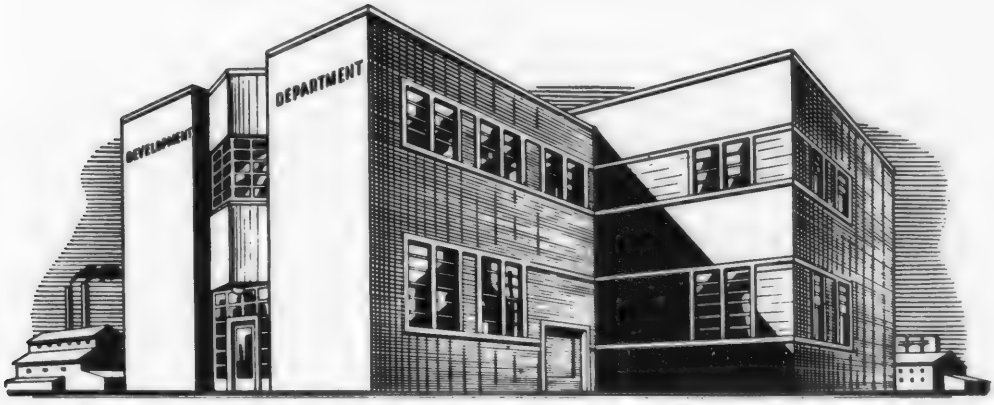

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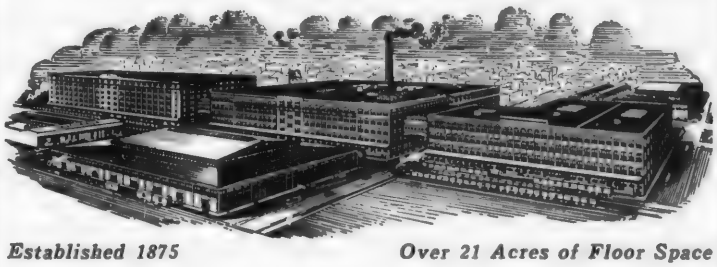

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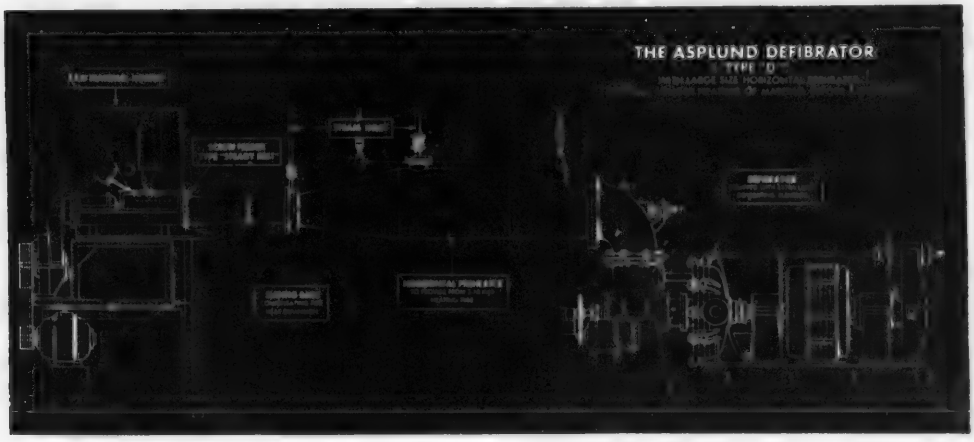

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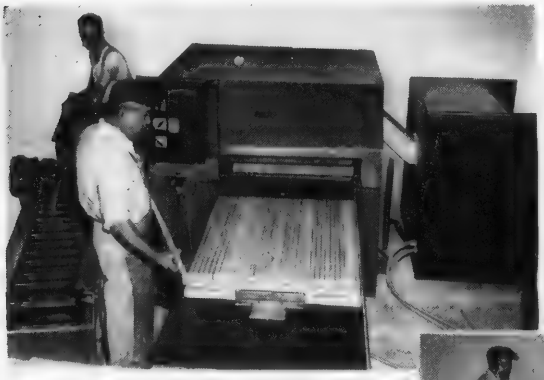

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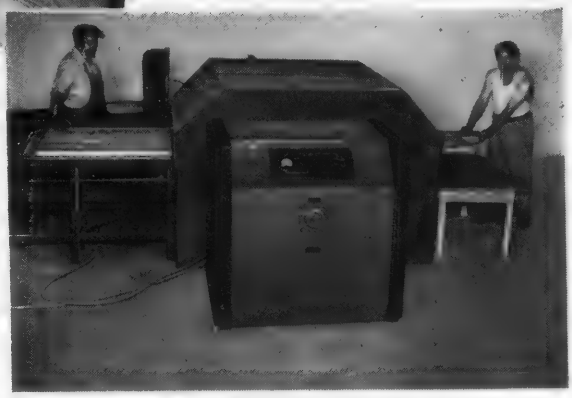

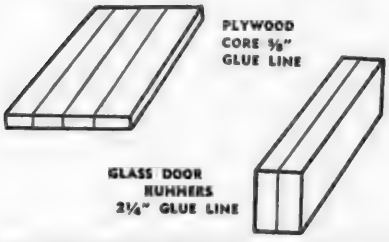

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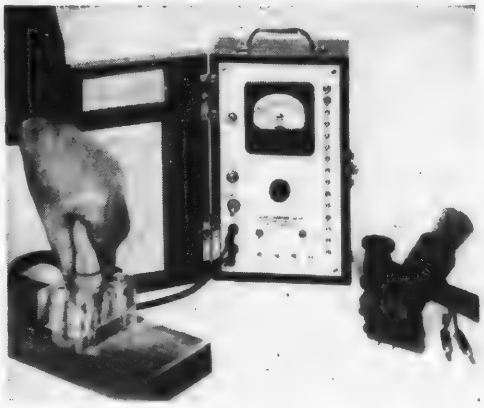

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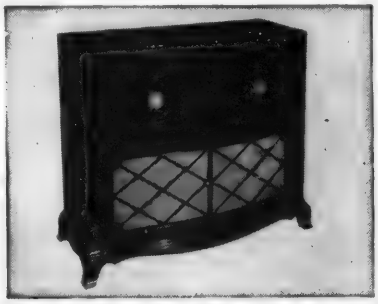

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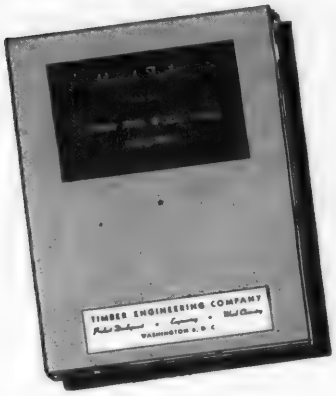

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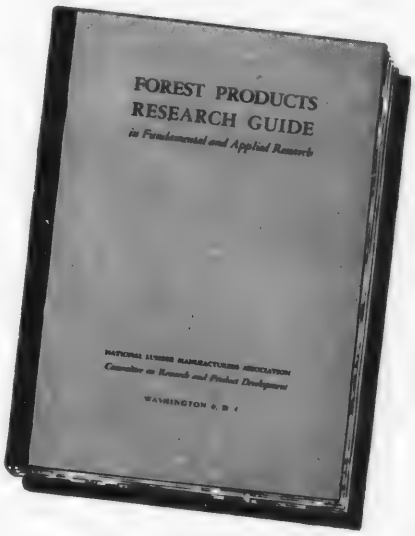

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Compare These Skin-Gluing Production Figures* With Your Own–

FLUSH DOORS	CURING TIME	PRODUCT. RATE DOORS/HR
Hollow-core, light construction, 800 sq in. core, two ¼" skins.	47 sec	80 to 73
Hollow-core, close aggregate, 1100 sq in. core, two ¼" skins.	58 sec	80 to 60
Solid-core slab doors, 2580 sq in. core, two ¼" skins.	113 sec	28 to 31
Solid-core slab doors, 2580 sq in. core, four 1/16" skins.	196 sec	17 to 18
PREFABRICATED HOUSE PANELS (¼" skins both sides)	**CURING TIME**	**PRODUCT. RATE PANELS/HR**
Window panel, 48"x96", 500 sq in core, 650 sq in. skins.	24 sec	87 to 126
Wall panel, 48"x 96", 700 sq in. core	58 sec	46 to 66
Wall panel, 96"x 96", 1400 sq in. core	115 sec	23 to 31
FURNITURE CHEST SIDES (¼" panel, one side)	**CURING TIME**	**PRODUCT. RATE PAIRS/HR**
13"x 44", 101 sq in. core, two pairs at a time.	14 sec	254 to 418
15"x 49", 187 sq in. core, one pair at a time.	12 sec	175 to 281

*Conservative figures for 15 kw Allis-Chalmers unit.

WITH ALLIS-CHALMERS high frequency heat, investment costs alone may be 50 to 75 percent lower than for hot-press installations.

Operating costs for a 15 kw unit are only 50c an hour, including power and tube replacement. And with conveyors, handling costs can also be substantially reduced. Curing one door or panel at a time automatically eliminates the incessant stacking and unstacking usually associated with the operation.

You can use water-proof or water-resistant glue in this high-speed, low-cost way for any arrangement of doors or panels, in any sequence. Only one set of electrodes is necessary regardless of successively different core structures; and you can do it all with push-button control.

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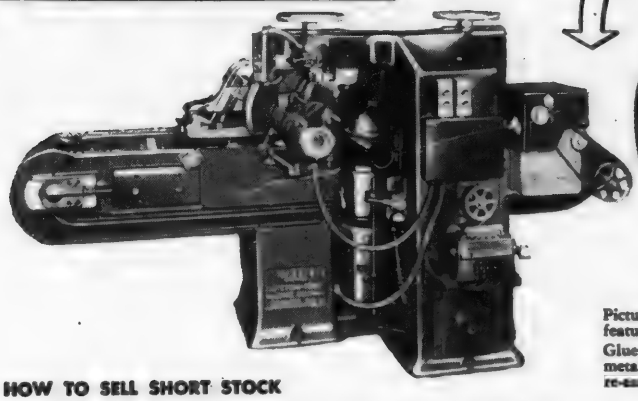

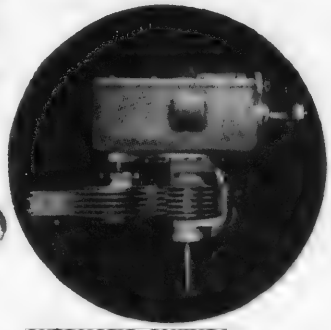

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Pictured above is the glue-spreading feature of this machine!

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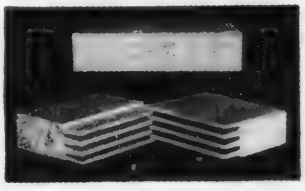

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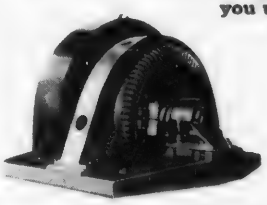

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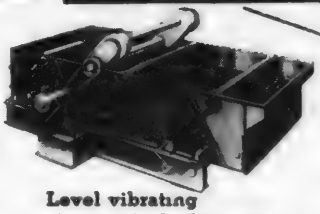

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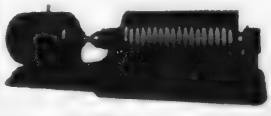

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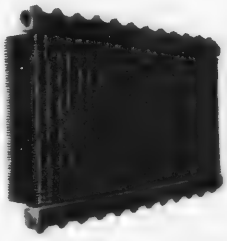

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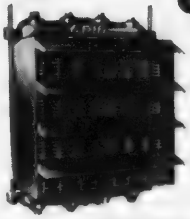

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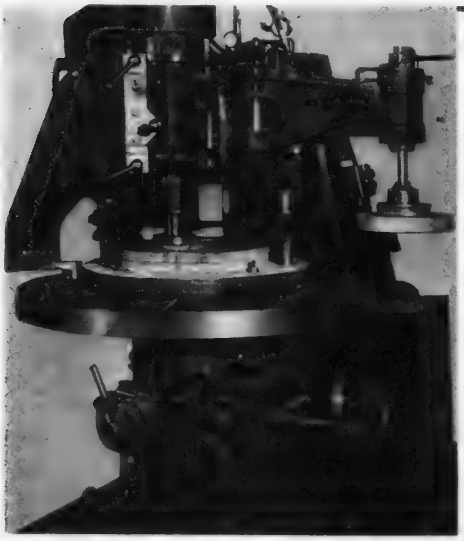

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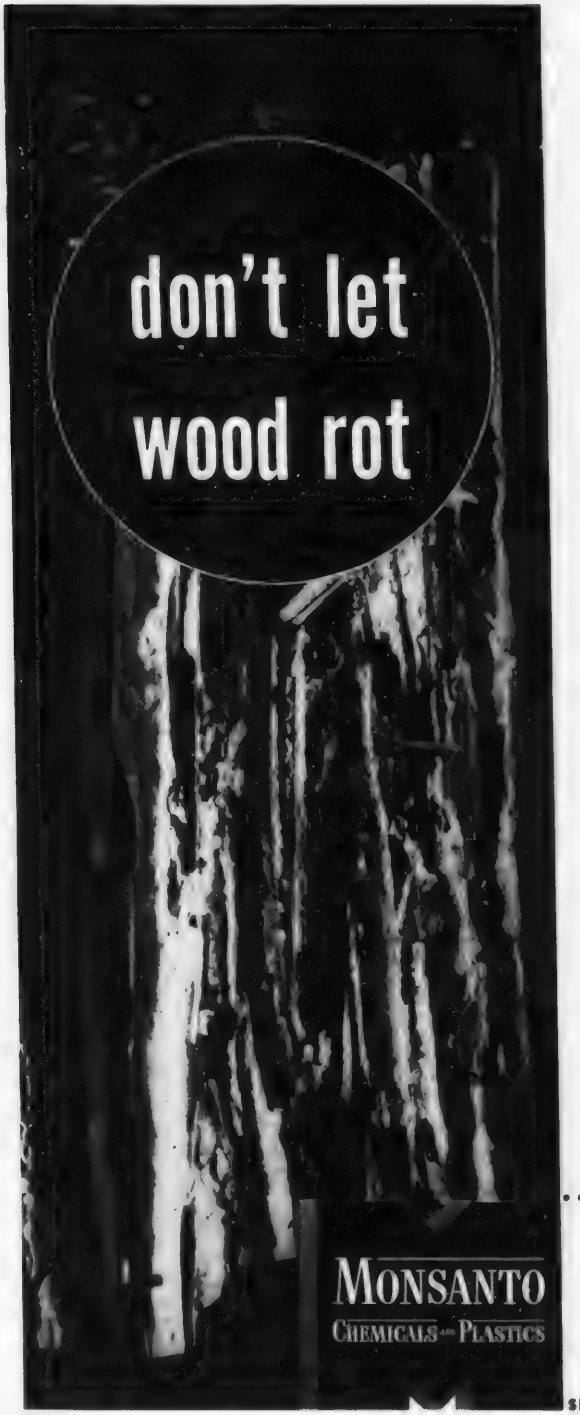

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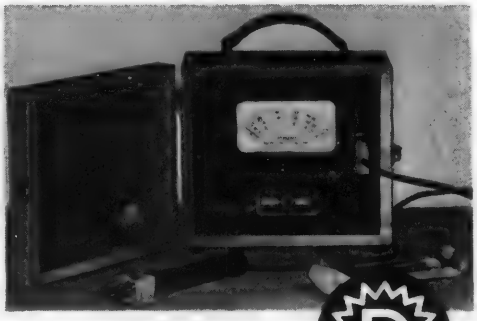

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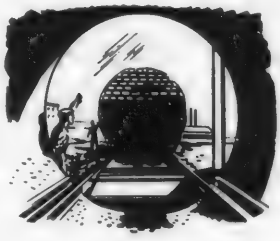

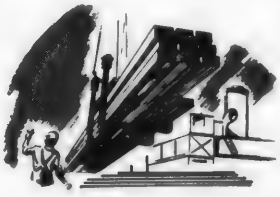

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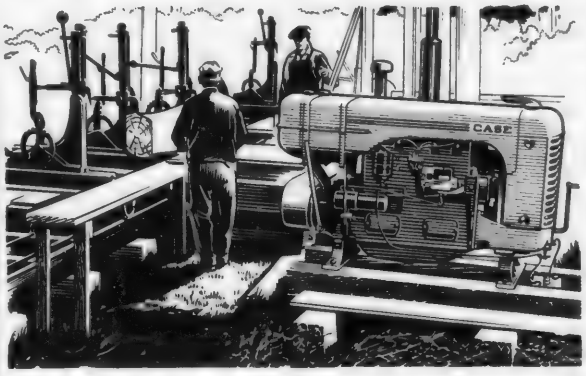

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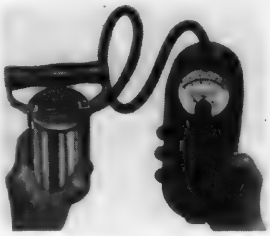

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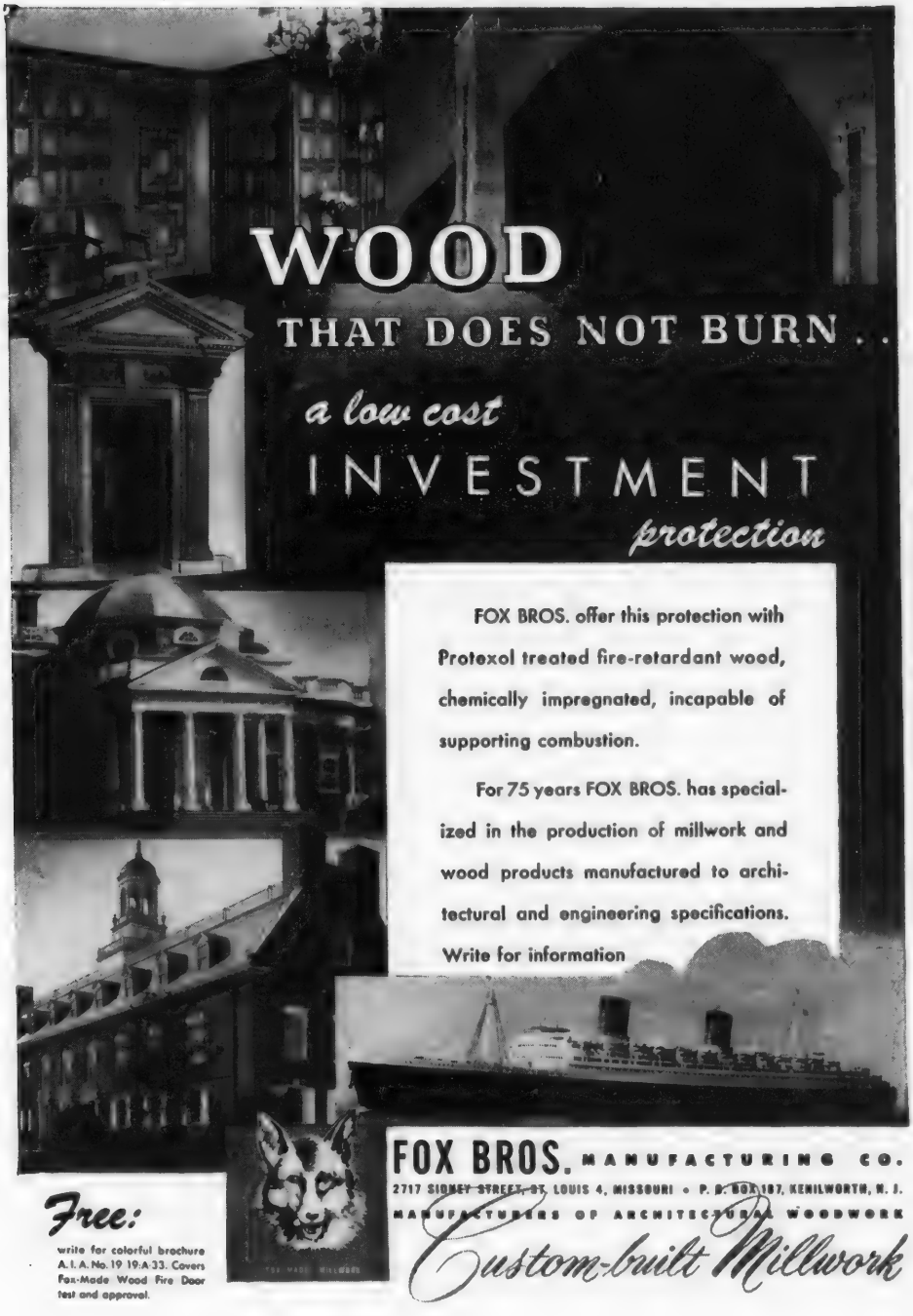
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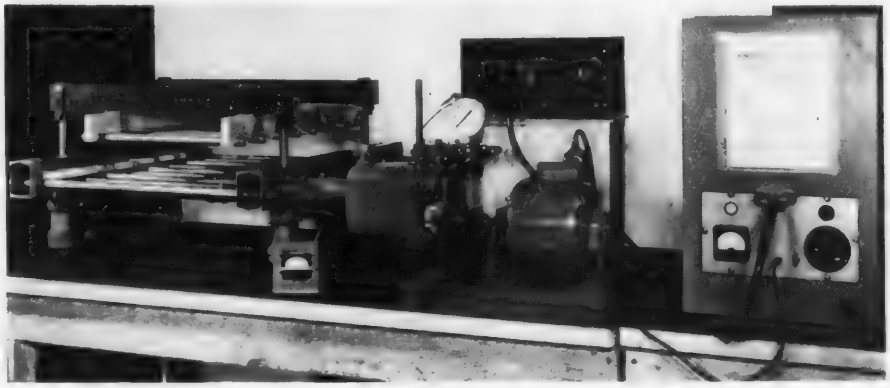

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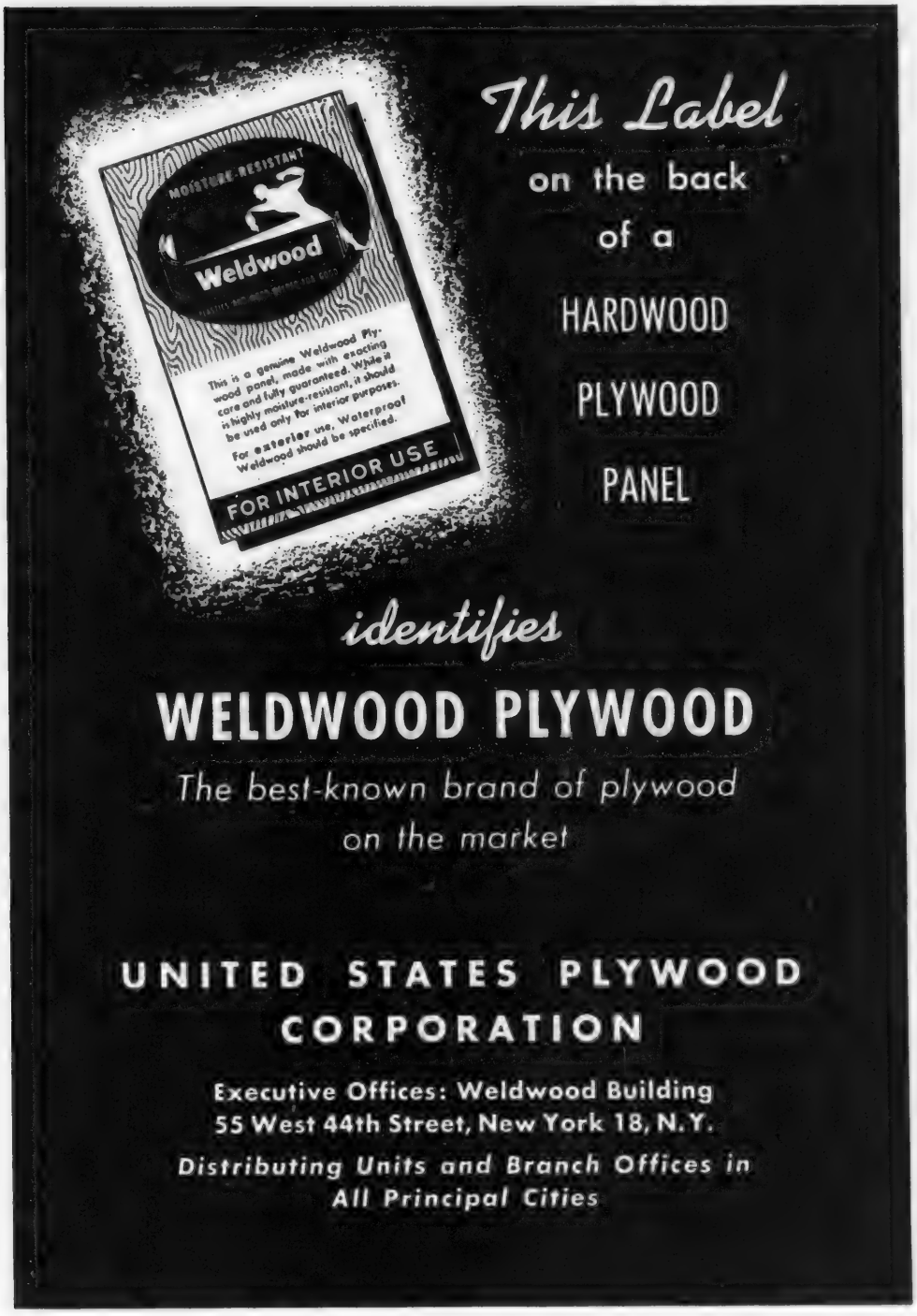
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